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PRODUCTION ENGINEERING MEASURE  
QUARTERLY PROGRESS REPORT NO. 4

PRODUCTION RELIABILITY  
IMPROVEMENT PROGRAM  
FOR  
GERMANIUM TRANSISTOR 2N1430

31 JANUARY 1963 TO 30 APRIL 1963

CONTRACT NO. DA-36-039-SC-86723

ORDER NO. 19045-PP-62-81-81

Placed by:

U. S. ARMY SIGNAL SUPPLY AGENCY  
PHILADELPHIA, PENNSYLVANIA

SEMICONDUCTOR PRODUCTS

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PRODUCTION RELIABILITY IMPROVEMENT PROGRAM FOR  
GERMANIUM TRANSISTOR 2N1430

PRODUCTION ENGINEERING MEASURE  
QUARTERLY REPORT NO. 4

31 JANUARY 1963 TO 30 APRIL 1963

OBJECT: To improve production techniques in order  
to increase the reliability and yield of the  
2N1430 Germanium Transistor.

Contract No. DA-36-039-SC-86723

Order No. 19045-PP-62-81-81

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I - ABSTRACT

Planning in all areas under study has been completed.

Equipment set-up has been completed except in those areas where refinement modifications are necessary.

Previous control production runs have been evaluated and the affected areas of study have been finalized where possible. Additional studies are or have been initiated to standardize the remaining areas of interest.

## II.- PURPOSE

The purpose of this measure is to:

1. Direct efforts toward improving production techniques to improve the reliability of the 2N1430 Germanium transistor using as an objective a maximum operating failure rate of 0.05% per 1000 hours at a 90% confidence level of 25°C.

2. Improve the areas of resistivity control, etch pit control, uniform penetration in diffusion, depth control in alloying, spreading and wetting in alloying, collector attachment, surface passivation, final preparation prior to sealing, gettering technique, and leak determination in order to approach the above objective.

3. Provide information and data to demonstrate the results in the areas of study.

4. Establish and maintain quality control measures to insure accuracy and reliability of the established process techniques.

### III. RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (Continued):

#### 1.1.1 Resistivity Control - H. Sivik

Work on preparing germanium crystals with a tighter radial resistivity gradient was completed in this quarter, as described below. Also, a series of crystals grown to specified resistivity range was submitted for a production run. Device results appear in later sections of this report. A total of twenty-four (24) crystals were prepared in this period. Largely due to excessive vibration from an electric motor, four (4) crystals were excluded from Table I having been rejected for strain and polycrystallinity. During the third (3rd) quarterly period, significant improvements were demonstrated in yield and the vertical resistivity gradient. Thus, the contract commitments on resistivity were successfully accomplished in the allotted time.

The effect of three (3) different size capillaries in the floating crucible was investigated by growing eight (8) crystals. Data on crystal numbers 1 thru 8 show no significant variation was obtained in the radial and vertical resistivity gradients when using floating crucibles having three (3) different size capillaries. This result is interpreted to mean that the transfer of dopant from the inner to the outer crucible is negligible under the operating conditions.

Several crystals were grown to observe the effect on angular seed rotation and pull speed on the radial resistivity gradient. In Table I, crystal numbers 9 thru 20 show that the radial resistivity gradient is noticeably affected by the seed rotation rate. For example, the five (5) crystals grown at 100 RPM exhibit a radial gradient below 5 percent compared to crystals grown at 10, 20, or 50 RPM, which exhibit a radial gradient--generally--in excess of 5 percent. The effect of 2 versus 3 inches per hour pull rate was not distinguishable under the operating conditions. These results were as anticipated. The relationship between pull rate, angular speed of rotation and effective segregation coefficient was given by the Burton-Prim-Slichter Formula\*.

$$k_{eff} = k_0 / \left[ k_0 + (1-k_0) \exp (-v/v_d) \right] \quad \text{Equation 1}$$

where:  $v = f\delta$

$\delta$  = thickness of layer in the liquid adjacent to solid-liquid interface (extending .1 - .00001 cm depending on RPM)

$f$  = growth rate

$v_d$  = characteristic growth constant mostly dependent on  $D$  ( $C'/C_0$ ).

$D$  = Diffusion constant in the liquid (Outdiffusion from the inner crucible to the outer crucible through the capillary).

$C'$  = Impurity concentration in the inner crucible.

$C_0$  = Impurity concentration in the outer crucible.

In the case of  $k_0 \ll 1$  (presently applied) Equation 1 may be simplified to:

$$k_{eff} \approx k_0 \exp f\delta/D \quad \text{Equation 2}$$

TABLE I

CRYSTAL NUMBER	TYPE FURNACE	RESISTIVITY OHM CM		BOT	% RESISTIVITY GRADIENT		TORUS HOLE		ETCH PITS PER CM <sup>2</sup>	USEABLE LENGTH	CRYSTAL DIAM	CAP SIZE IN.	SEED ROT'N RPM	PULL SPD IN/ HR	REMARKS
		TOP			RADIAL	VERT INCH	DIAM INCH								
1	F1 Cruc	17-15.2		15-14	5.5	1.3	none	3500-4300	8.2	1.2-1	.093	50		2-3/4	-----
2	F1 Cruc	29-26		20-16.5	6.0	4.2	none	2300-5700	9.5	.9-.8	.093	50		3	Missed Doping
3	F1 Cruc	8.0-7.0		7.5-5.5	5.3	1.6	1-1/2	1500-4000	8.5	.8-.7	.093	50		3	-----
4	F1 Cruc	24-19.2		18-16.5	11.1	2.0	1-1/2	2000-3000	11-1/2	.9-.6	.093	50		3	-----
5	F1 Cruc	26-23		19-18	6.6	3.3	none	1900-1600	8.5	.8-.6	.149	50		3	Missed Doping
6	F1 Cruc	14-10.5		10.5-9.0	14.2	2.6	none	2000-1600	9	.8-.7	.060	50		3	-----
7	F1 Cruc	12-11		9.8-9.0	4.3	2.5	none	1700-1700	8	1-.9	.093	62		2-3/4	Max RPM of Motoi
8	F1 Cruc	15-13.8		12-10	4.2	3.2	1-1/4	800-700	7.5	1.1-1.0	.093	62		2-3/4	Max RPM of Motoi
9	NRC	13-11.8		6.5-6.0	4.8	10.4	1-1/4	160-380	6.3	1-.9	----	100		2	-----
10	NRC	13.5-13		12.2-11.5	1.8	3.9	1-3/4	1220-1300	3	.9	----	100		2	-----
11	NRC	9.4-8.5		9.0-8.5	4.9	0.8	1	20-20	4.5	.6-.7	----	100		2-3/4	-----
12	NRC	17.1-15.6		12-11.5	4.6	5.5	1-1/8	200-100	6	.6-.7	----	100		2-3/4	-----
13	NRC	14.1-13		11.2-9	4.8	4.9	1-1/4	200-300	6	.6-.7	----	100		2-3/4	-----
14	NRC	16-13		11.2-9.8	10.3	5.2	1-1/4	600-500	6.2	.7-.8	----	20		2-3/4	-----
15	NRC	18-12.8		9.5-7.2	16.8	9.2	1-1/4	200-700	6.5	.9-.7	----	10		2	-----
16	NRC	28-25		21-18.5	5.9	9.7	1-1/4	420-480	3	.6-.7	----	50		2-3/4	Missed Doping
17	NRC	19.8-14.5		16.2-12.2	15.5	6.9	2	1900-2120	3	.6-.7	----	50		2-3/4	-----
18	NRC	17-15.2		13-10.8	5.5	8.5	1-3/4	1160-1520	3.5	.8	----	50		2-3/4	-----
19	NRC	5.0-4.8		4.8-4.5	2.0	1.0	1	20-20	6.5	.5-.4	----	50		2-3/4	Small d- Crystal
20	NRC	11.5-10		9-8.2	7.0	4.0	2	1700-1100	5	.6-.5	----	50		2-3/4	



### III. RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (Continued):

#### 1.1.1 Resistivity Control - H. Sivik

Equation 2 is sensitive to higher pulling speeds (above 10 inches per hour) but relatively insensitive to pulling speeds below 3 inches per hour. At low rotational speed ( $\sim 10$  RPM)  $\delta$  assumes 0.1 to .01 values. At higher rotational speeds ( $> 50$  RPM) the  $C' > C_0$  condition is easily maintained since  $C' = C_0/k_{eff} = C_0/k_0 \exp \pi \omega / D$  and  $\delta$  decreases as rotation increases; where  $C'$  = concentration of dopant in the inner crucible and  $C_0$  = concentration of dopant in the outer crucible. Thus, the increased agitation of the melt, resulting from the greater shearing action at the liquid-solid interface, has decreased the radial resistivity gradient considerably by enhancing redistribution of impurity in the body of the melt.

#### Conclusions:

Improvement in the radial resistivity gradient was demonstrated by use of higher rotational speeds.

Effects of crystal pull speed and different size of capillary in the inner crucible were found to be negligible on the radial resistivity under the furnace operating conditions.

#### Program for Next Quarter:

None, this portion of the program is essentially completed and will be summarized in the final report.

### III. RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (Continued):

#### I 1.2 Etch Pit Control - H. Sivik

Several crystals with specified etch pit count and resistivity were prepared and submitted for a production run as explained in Section 1.1.1. No difficulty was encountered in preparing these crystals with the required 1,000 - 2,000 etch pits range, other than the normal minor mechanical troubles.

Three (3) crystals (Numbers 11, 12, 19 in Table I) made with the 1 or 1-1/8 inch torus hole show 20, 200, and 20 etch pits per  $\text{cm}^2$ , respectively. Such low dislocation densities are not desired for the 2N1430 device as was indicated in Section 1.1.5 of a previous report due to spreading and alloying problems. However, these crystals demonstrate the etch pit control attainable by use of the torus in fulfillment of the goal of  $< 200$  etch pits per  $\text{cm}^2$  in the work statement of Supplement No. 2 of the technical proposal.

#### Conclusion:

The ability to prepare germanium crystals of desired dislocation count was shown to be feasible and reproducible.

#### Program for Next Quarter:

None, this portion of the program is essentially completed and will be summarized in the final report.

### III. RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (Continued)

#### 1.1.3 Uniform Penetration in Diffusion - R. Colucci

Although the silicon-dioxide mask process appears to hold definite advantages in regard to cost and uniformity of electrical characteristics, there were problems, discussed in the third quarterly report, which made it impossible to incorporate the process in the pilot production run. Bendix plans to continue this work beyond the present contract until a workable production process is arrived at or the process is definitely determined to be not feasible.

### III. RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (Continued)

#### 1.1.4 Depth Control in Alloying - F. Arden

In Quarterly Report #2 it was indicated that as an improvement to the depth control in alloying, the thickness of the dice would be regulated statistically with the help of a control chart.

In the following Report #3, an evaluation of the effectiveness of the technique was discussed, and the conclusion was made that the results had proved satisfactory.

Since then, the statistical technique has been used exclusively, and the yields attributable the thickness of the dice have stayed at a markedly high proportion.

### III. RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (Continued)

#### 1.1.5 Spreading and Wetting in Alloying - R. Colucci

As the depth control in alloying is also affected, it will be necessary in all cases to consider spreading and wetting in alloying in conjunction with "1.1.4 Alloy Depth Control in Alloying" since depth penetration and surface spreading are closely dependent on one another.

See 1.1.4 for finalized production techniques and processes.

### III. RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (Continued)

#### 1.1.6 Collector Attachment - R. Colucci

It can be concluded at this time that the collector attachment has been finalized to the use of the ultrasonic mounting technique as outlined in the first quarterly report. This technique has been used in the Production Reliability Run and will be presented on the finalized flow chart.

### III. RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (Continued)

#### 1.1.7 Surface Passivation and Final Preparation Prior to Sealing. - R. Colucci

The present production techniques have been finalized. Quality Control's "Lot Control System" shows that gain degradation of the present product is  $\pm 5\%$  after 1000 hours storage at  $110^{\circ}\text{C}$  and  $\pm 8\%$  after 10,000 hours, indicating adequate surface passivation control.

### III. RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (Continued)

#### 1.1.8 Gettering Techniques - R. Colucci

The production gettering technique has been finalized to the use of an activated molecular sieve pellet. This technique has been used in the Production Reliability Run and will be presented on the finalized flow chart.



#### 1.1.9 Leak Determination - E. Yurowski

The mass spectrometer helium leak detection study was concluded as described in Report No. 3. The results of the helium leak detection study have been incorporated as part of normal production on the 2N1430 transistor and its related generic types. The test procedure as it is now applied includes helium leak testing to a limit of  $1.0 \times 10^{-10}$  std cc He/sec, preconditioned by backfilling at 100 psi for four (4) hours. Gross leakers, i.e., leak rates of greater than  $1.0 \times 10^{-5}$  std cc He/sec. are withdrawn during subsequent testing by the Detergent Bomb Hermetic Seal Test performed at 100 psi for thirty (30) minutes.

**TABLE I**  
**2N1430**  
**TEST SPECIFICATIONS**

		LIMITS				TEST CONDITIONS												
LINE	TESTS	% AQL	SYMBOL	MIN.	MAX.	UNIT	NOTES	V <sub>CB</sub> V <sub>dc</sub>	V <sub>CE</sub> V <sub>dc</sub>	I <sub>E</sub> A <sub>dc</sub>	I <sub>B</sub> A <sub>dc</sub>	R <sub>BE</sub> OHMS	V <sub>CC</sub> V <sub>dc</sub>	T °C	V <sub>EB0</sub> V <sub>dc</sub>	f kc		
1	Collector Cutoff Current	1.0	ICBO		-300	μA <sub>dc</sub>		-1.5						25				
2	Collector Cutoff Current	1.0	ICBO		-50	mA <sub>dc</sub>		-100						25				
3	Emitter Cutoff Current	1.0	IEBO		-50	mA <sub>dc</sub>								25	-1.5			
4	Collector Current	1.0	ICEO		-100	mA <sub>dc</sub>			-40			∞		25				
5	Collector Current	1.0	ICER		-50	mA <sub>dc</sub>			-80			100		25				
6	Base Current	1.0	I <sub>B</sub>	-50	-165	mA <sub>dc</sub>			-2.0	5.0				25				
7	Base Current	1.0	I <sub>B</sub>		-500	mA <sub>dc</sub>			-2.0	10				25				
8	Base Voltage	1.0	V <sub>BE</sub>		-0.9	V <sub>dc</sub>			-2.0	10				25				
9	Collector Saturation Volt.	1.0	V <sub>CE(S)</sub>		-0.75	V <sub>dc</sub>				10	-1.0			25				
10	Current Gain	4.0	h <sub>fe</sub>	7.5					-6.0	50				25		100		
11	Rise Time	4.0	t <sub>r</sub>		5	μsec				5.0			-28	25				
12	Fall Time	4.0	t <sub>f</sub>		2	μsec				5.0			-28	25				
13	Thermal Resistance	4.0	θ <sub>r</sub>		1.5	°C/W	1											
14	Base Current	4.0	I <sub>B</sub>	-50	-165	mA <sub>dc</sub>	2		-1.5	5.0				80				
15	Life Test (storage)	4.0	I <sub>B</sub>															
RATINGS ABS. MAX. (at 25 °C)		MIL. SCL-7002, 25A				Life Test 1000 hrs.										End Points		
SYMBOL	MAX	UNIT					SYMBOL	COND	MAX	UNIT								
V <sub>CB</sub>	-100	V <sub>dc</sub>					IEBO	Line 3	-75	mA <sub>dc</sub>								
V <sub>CE</sub>	-40	V <sub>dc</sub>					ICBO	Line 2	-75	mA <sub>dc</sub>								
V <sub>EB</sub>	-1.5	V <sub>dc</sub>					I <sub>B</sub>	Line 7	-625	mA <sub>dc</sub>								
IC	-10.0	A <sub>dc</sub>																
PC	50	W																
T <sub>j</sub>	+100	°C																
T storage	+100	°C																

NOTES:

1. Junction to mounting base.
2. 1000 hours at 100 °C.

THE BENDIX CORPORATION

TABLE II  
2N 1430 PROPOSED  
TEST SPECIFICATIONS

DESCRIPTION:	CATEGORY:
APPLICATION:	EIA:
CLASS:	BENDIX:
DATA SOURCE:	CUSTOMER:
WRITER:	CUSTOMER NAME:
	CUSTOMER SPEC:

Rev.	Changes No.	APPROV.	DATE	CHANGE

LIMITS										TEST CONDITIONS									
LINE	TESTS	% AQL	SYMBOL	MIN.	MAX.	UNIT	NOTES	V <sub>CB</sub> Vdc	V <sub>CE</sub> Vdc	I <sub>C</sub> Adc	I <sub>B</sub> mAdc	R <sub>BE</sub> OHMS	T °C						
1	Collector Cutoff Current	1.0	I <sub>CBO</sub>		-200	uAdc		-2											
2	Collector Cutoff Current	1.0	I <sub>CBO</sub>		-5	mAdc		-120											
3	Collector Cutoff Current	1.0	I <sub>CBO</sub>		-10	mAdc		-100					85						
4	Collector Cutoff Current	1.0	I <sub>CES</sub>		-10	mAdc			-120			0							
5	Base Current	1.0	I <sub>B</sub>		500	mAdc			-2	-10									
6	Base Current	1.0	I <sub>B</sub>	56	167	mAdc			-2	-5									
7	Collector Saturation Volt.	1.0	V <sub>CE(S)</sub>		-0.4	Vdc				-10	-1000								
8	Saturation Voltage	1.0	V <sub>BE(S)</sub>		-0.9	Vdc				-10	-1000								
9	Collector-Emitter Brkdn V.	1.0	V <sub>CEO</sub>	-100		Vdc	1			-0.10		00							
10	Collector-Emitter Brkdn V.	1.0	V <sub>CEO</sub>	-100		Vdc	2			-2.0									
11	Emitter to Base Brkdn V.	1.0	V <sub>EB0</sub>	-1.5		Vdc					50								
12	Rise Time	4.0	t <sub>r</sub>		7	us	3												
13	Fall Time	4.0	t <sub>f</sub>		5	us	3												
14	Storage Time	4.0	t <sub>s</sub>		3	us	3												
15	Life Test (Storage)	4.0					4												

RATINGS ABS. MAX. (at 25 °C)										MIL. SCL-7002/25A									
SYMBOL	MIN.	MAX.	UNIT							SYMBOL	COND.	hrs.	MIN.	MAX.	UNIT				
V <sub>CB</sub>		-120	Vdc							I <sub>CBO</sub>	Line 2			-7.5	mAdc				
V <sub>CEO</sub>		-100	Vdc							I <sub>B</sub>	Line 5			-625	mAdc				
I <sub>C</sub>		-10	Adc							I <sub>EB0</sub>	Line 11			75	mAdc				
P <sub>C</sub>		70	W																
T <sub>J</sub>		110	°C																
T <sub>stg</sub>	-65	110	°C																
I <sub>B</sub>		-1.5	Adc																

NOTES:  
 1. Full wave curve tracer  
 2. See Page 3 A  
 3. See Page 3 B  
 4. 1000 hours at 110° C.  
 5. Mechanical and environmental requirements of SCL-7002/25A must be met.

[illegible][illegible]

## TABLE II

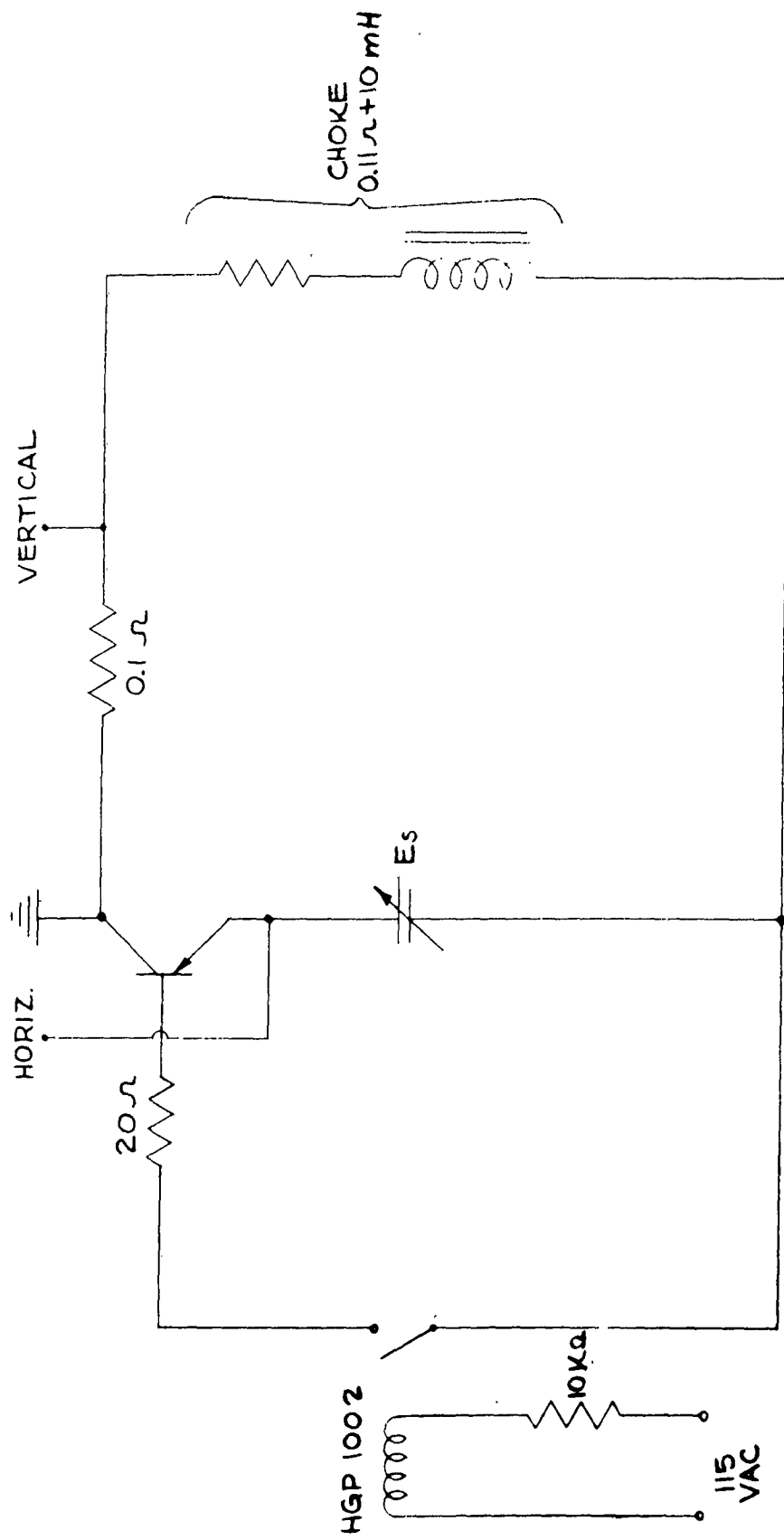
**2M 1430 PROPOSED**

## TEST SPECIFICATIONS

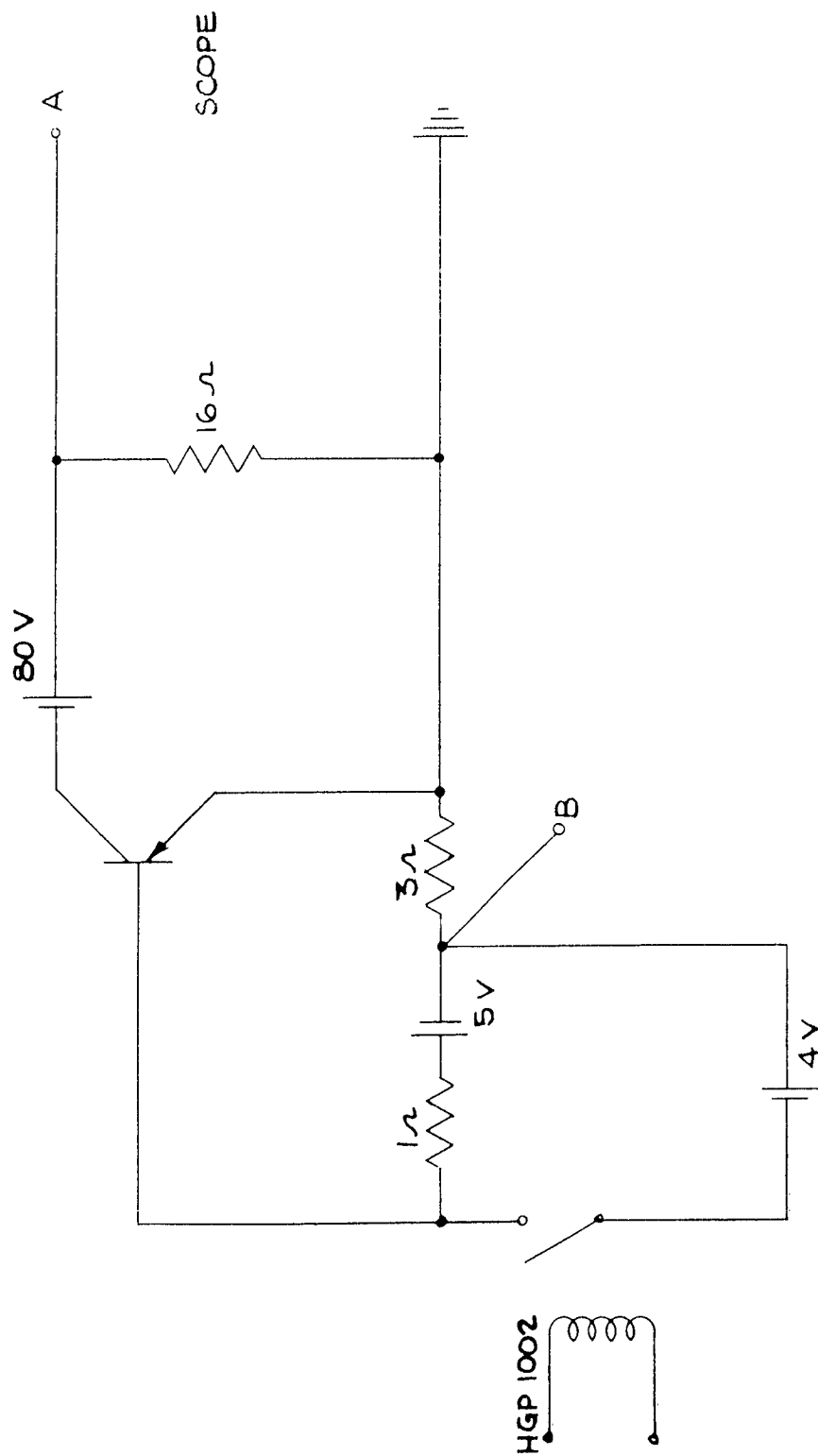
DESCRIPTION:	CATEGORY:
	— TYPE —
APPLICATION:	EIA:
	BENDIX:
CLASS:	CUSTOMER:
DATA SOURCE:	CUSTOMER NAME:
WRITER:	CUSTOMER SPEC:

[illegible][illegible]

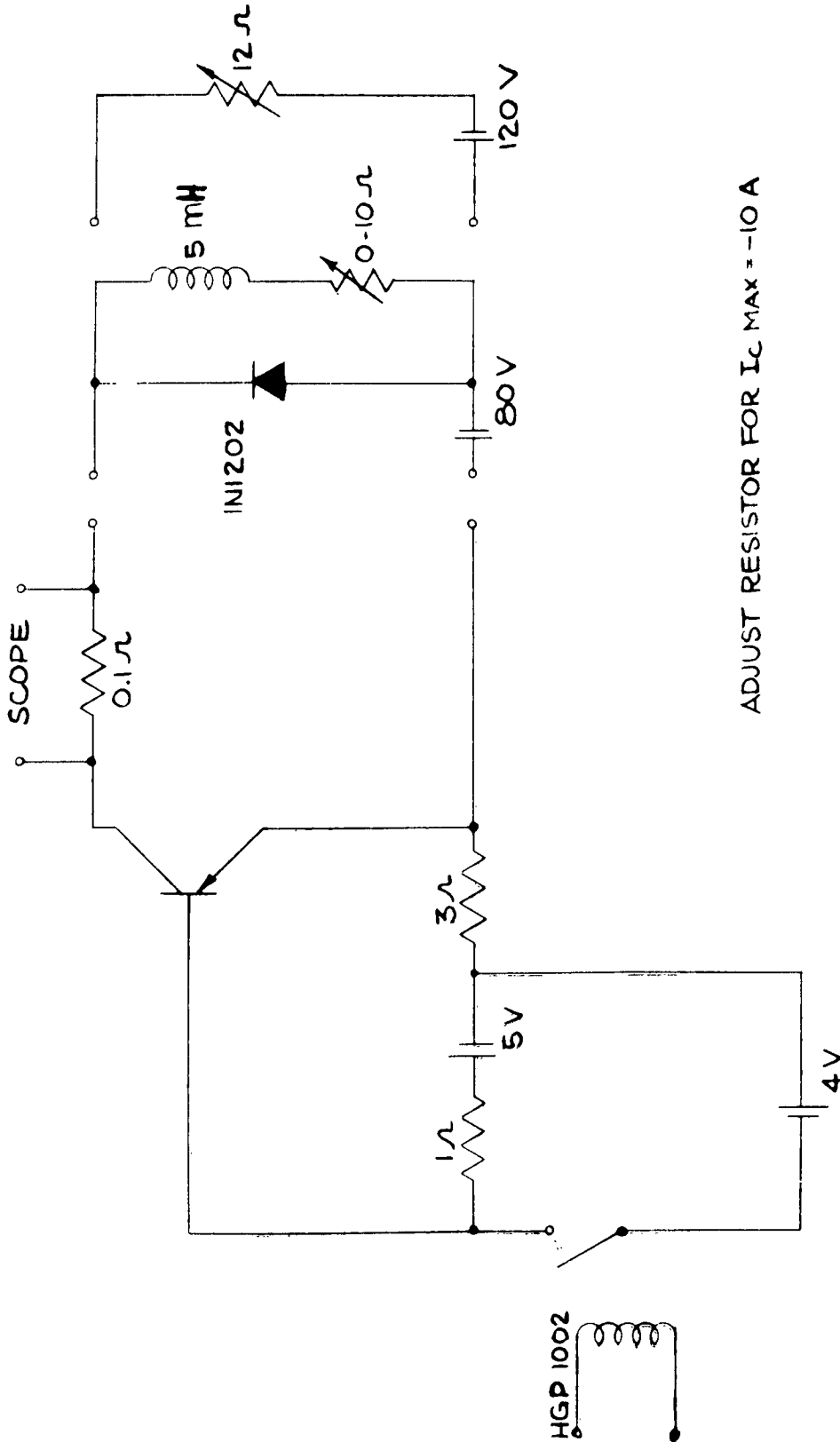
INDUCTIVE SWEEP TEST



RISE, FALL, STORAGE TIME



LOAD LINE SWITCHING TEST



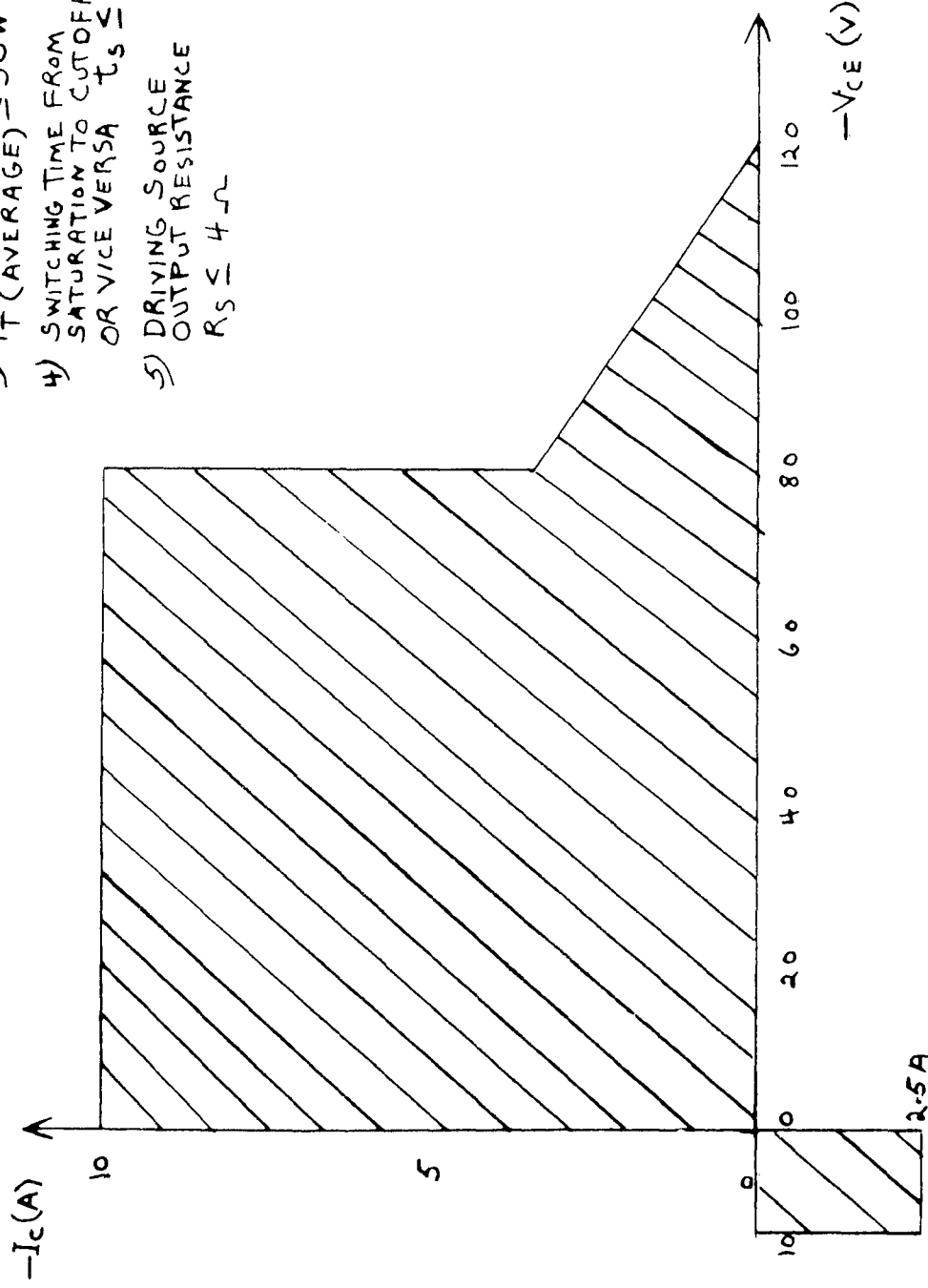
ADJUST RESISTOR FOR  $I_C \text{ MAX} = -10 \text{ A}$

# SAFE OPERATING AREA

2N1430 TEST SPECIFICATIONS

FOR THE FOLLOWING CONDITIONS:

- 1)  $V/I_B \leq 1A$
- 2)  $T_J \leq 110^\circ C$
- 3)  $P_T (AVERAGE) \leq 30W$
- 4) SWITCHING TIME FROM SATURATION TO CUTOFF OR VICE VERSA  $t_s \leq 50 \mu S$
- 5) DRIVING SOURCE OUTPUT RESISTANCE  $R_S \leq 4 \Omega$



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5/20/63



MIL-S-19500/

(PROPOSED)  
MILITARY SPECIFICATION  
TRANSISTOR, PNP, GERMANIUM  
TYPE 2N1430

1. SCOPE

1.1 Scope. This specification covers the detail requirements for a Germanium Diffused Alloy PNP switching transistor with the following characteristics at  $T_J = 25^\circ\text{C}$ .

1.2 Absolute Maximum Ratings.

SYMBOL	$P_T^{(1)}$ Average	$P_T^{(2)}$	$T_{STG}$	$T_J$	$BV_{CBO}$	$BV_{CEO}$	$I_C$	$I_B$
UNIT	W	W	$^\circ\text{C}$	$^\circ\text{C}$	V	V	A	A
MAX.	70	800(peak) 30(avg)	-65 to 110	110	-120	-100	-10	$\leq 1.5$

NOTES:

1. For steady state conditions with forward bias

$$P_T = \left| I_C V_{CB} \right| + \left| I_E V_{EB} \right| \quad \text{derate } 1.2^\circ\text{C/W for case temperatures } 25^\circ\text{C}.$$

2. Peak and average power in switching applications derate  $1.2^\circ\text{C/W}$  for case temperatures  $> 74^\circ\text{C}$ . See Figure 3 for safe operating power dissipation area.

1.3 Primary Electrical Characteristics.

SYMBOL	$h_{FE}$	$V_{CE(S)}$	$V_{BE(S)}$	$t_r$	$t_s$	$t_f$
CONDITIONS	$I_C = -10\text{A};$ $V_{CE} = -2\text{V}$	$I_C = -10\text{A}; I_B = -1\text{A}$	$I_C = -10\text{A}; I_B = -1\text{A}$	$I_C = -5\text{A}$		$V_{CC} = 80\text{V}$
UNIT	--	V	V	$\mu\text{s}$	$\mu\text{s}$	$\mu\text{s}$
MIN.	20	-----	-----	----	----	----
MAX.	60	-0.4	-0.9	7.0	3.0	5.0

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on invitation to bids form a part of this specification:

Specifications:

Military:	MIL-S-19500	Transistors, General Specification for
Standards:	MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes and Appendix, Sampling for Expensive Testing by Attributes
	MIL-STD-202	Test Methods for Electronics and Electrical Component Parts
	MIL-STD-750	Test Methods for Semiconductor Devices

3. REQUIREMENTS

3.1 Requirements: Requirements shall be in accordance with Specification MIL-S-19500,

and as specified herein.

3.2 Abbreviations and symbols. The abbreviations and symbols used herein are defined in Specification MIL-S-19500 and as follows:

hFE	Static Forward Current, Transfer Ratio
VCE(sat)	Collector Saturation Voltage
$\theta_{J-C}$	Thermal Resistance, Junction to Case
ICEO	Collector to Emitter Cutoff Current, Base Open
ICBO	Collector Cutoff Current
IEBO	Emitter Cutoff Current
ICER	Collector to Emitter Cutoff Current, Resistance return from base to emitter
ICES	Collector Cutoff Current, Base Shorted
$t_r$	Pulse Rise Time
$t_f$	Pulse Fall Time
$t_s$	Storage Time

3.3 Design and Construction. Transistors shall be of the design, construction and physical dimensions specified on Figure 1.

3.4 Lead Arrangement. The lead arrangement shall be as indicated on Figure 1.

3.5 Operating Position. Transistors shall operate in any position.

3.6 Performance Characteristics. Performance characteristics shall be as specified in Tables I, II.

3.7 Marking. In addition to the marking specified in Specification MIL-S-19500 transistors shall be marked with the appropriate type designations and U. S. Army prefix after qualification has been obtained, and with the qualification code and manufacturer's identification.

#### 4.0 QUALITY ASSURANCE PROVISIONS

4.1 Sampling and Inspection. Sampling and inspection shall be in accordance with specification MIL-S-19500 and as specified herein.

4.2 Qualification Inspection. Qualification inspection shall consist of the examinations and tests specified in Tables I and II.

4.3 Inspection Conditions. Inspection shall consist of the examinations and tests specified in Tables I and II.

4.4 Group A Inspection. Group A inspection shall consist of the examinations and tests specified in Table I.

4.5 Group B Inspection. Group B inspection shall consist of the examinations and tests specified in Table II.

4.6 Disposition of sample units. Sample units which have been subjected to and have passed Group B inspection may be delivered on the contract or order, provided that, after Group B inspection is terminated, these sample units are subjected to and pass Group A inspection.

4.6.1 LIFE TESTS. Life tests shall be performed on sample units which have been subjected to and have passed Group A inspection.

4.6.2 1000 Hours Life Tests.

- (a) 1000 hours life tests shall be in effect initially and shall continue in effect until the eligibility criteria for reduced hours life test have been met.
- (b) The measurements listed under end points in Table II shall be made at 0 hours,  $340 + 72 - 24$  hours,  $670 + 72 - 24$  hours, and  $1000 + 72 - 24$  hours. Additional readings may be taken at the discretion of the manufacturer.
- (c) Sample units shall meet the criteria specified in Table II.

If a life test sample fails either the 340 or 670 hour acceptance criteria for storage life or operation life, the lot shall be rejected. The tests may be terminated at the discretion of the manufacturer. However, the results of either of these tests shall not be used at a future date for acceptance of the same lot.

4.6.3 Reduced hours life tests. (670 or 340 hours) To qualify for reduced hours life tests, the following criteria shall be met:

- (a) The immediately preceding 5 lots have been accepted.
- (b) The average per cent defective over the preceding five lots at full test time has not exceeded 0.2 of  $\lambda$ .
- (c) There has been no unusual discontinuity in production in the immediately preceding 5 lots.

4.6.4 After establishing eligibility, production lots shall be released for shipment at 670 hours or 340 hours, provided the life test sample has not exhibited more than the allowable number of failures.

4.6.5 The manufacturer shall establish eligibility for 670 hours first, thence he shall meet the criteria of a, b and c of 4.6.3 at 670-hour release to qualify for 340-hour release. Lots which are accepted under early shipment may be shipped. However, the life test shall continue through the full 1000 hours. The manufacturer shall lose eligibility for 670-hour or 340-hour release whenever two of five consecutive lots have failed the life test or the percentage defective over the preceding five lots exceeds 0.4 of  $\lambda$  at full time. Loss of eligibility for 670-hour release shall result in institution of 1000 hour release. Loss of eligibility for 340-hour release shall result in institution of 670-hour release.

4.6.6 Resubmitted lots. Lots, from which defectives have been screened out or reworked and which are resubmitted for acceptance inspection, shall contain only devices which were in the original lot. Resubmitted lots shall be kept separate from new lots and shall be clearly identified as resubmitted lots. Resubmitted lots shall be inspected for all characteristics, using tightened inspection, only for the characteristics failed. Lots may be resubmitted a maximum of two times. At the discretion of the Government, testing of characteristics which are not affected by the screening process may be omitted for resubmitted lots.

4.7 Rise and fall time. Rise and fall time measurements shall be made using the circuit of Figure 2.

5. PREPARATION FOR DELIVERY

5.1 Preparation for delivery shall be in accordance with Specification MIL-S-19500.

6. NOTES

6.1 Notes. In addition to the notes specified herein, the notes specified in Specification MIL-S-19500 are applicable to this specification.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

TABLE I. GROUP A INSPECTION

EXAMINATION OR TEST	CONDITIONS	LTPD	MINIMUM REJECTION NUMBER	SYMBOL	LIMITS		UNITS
					MIN.	MAX.	
<b>SUBGROUP 1</b>							
Visual & Mechanical Examination	Method 2071	10	5	- - -	- - -	- - -	- - -
<b>SUBGROUP 2</b>							
Collector to Base Cutoff Current	Method 3036 VCB=-2Vdc IE = 0	5	4	ICBO	- - -	-0.20	mAdc
Collector to Base Cutoff Current	Method 3036 VCB = -120Vdc			ICBO	- - -	-5.0	mAdc
Collector to Emitter Cutoff Current	Method 3041 VCE = -120Vdc RBE = 0			ICES	- - -	-10.0	mAdc
Breakdown Voltage Emitter to Base	Method 3026 Cond. D IE = -50mA			BVEBO	-1.5	- - -	Vdc
Breakdown Voltage Collector to Emitter	IC = -100mA 120 cycle Repetitive Sweep			BVCEO	-100	- - -	Vdc
<b>SUBGROUP 3</b>							
Forward Current Transfer Ratio	Method 3076 VCE = -2Vdc IC = -5Adc	5	4	hFE	30	90	- - -
Forward Current Transfer Ratio	Method 3076 VCE = -2Vdc IC = -10Adc			hFE	20	- - -	- - -
Collector-to-emitter, Saturation voltage	Method 3071 IB = -1Adc IC = -10Adc			VCE(sat)	- - -	-0.40	Vdc

1. Methods referenced are contained in Standard MIL-STD-750

TABLE I. GROUP A INSPECTION

EXAMINATION OR TEST	1*	LTPD	MINIMUM REJECTION NUMBER	SYMBOL	LIMITS		UNITS
					MIN.	MAX.	
SUBGROUP 3 (Continued) Base to Emitter Saturation voltage  SUBGROUP 4 Switching Time Rise Time Storage Time Fall Time	Method 3066 $I_B = -1\text{Adc}$ $I_C = -10\text{Adc}$  See Figure 2	5   10	4   5	$V_{BE(sat)}$   $t_r$ $t_s$ $t_f$	- - -   - - - - - - - - -	-0.90   7.0 3.0 5.0	Vdc   $\mu\text{sec}$ $\mu\text{sec}$ $\mu\text{sec}$
SUBGROUP 5 Collector-Emitter Breakdown Voltage	See Figure 4 $I_C = 2.0 \text{ Amps}$	10	5	$BV_{CEO}$	100	----	Vdc

1\* Methods referenced are contained in Standard MIL-STD-750

TABLE II  
GROUP B INSPECTION

EXAMINATION OR TEST	CONDITION	L <sup>1</sup>	LTPD	MINIMUM REJECTION NUMBER	SYMBOL	LIMITS		UNITS
						MIN.	MAX.	
<u>Subgroup 1</u> Physical Dimensions	Method 2066		20	4	- - -	-	-	-
<u>Subgroup 2</u> Solderability	Method 2026		10	5	- - -	-	-	-
Temperature Cycling	Method 1051 Cond. C $T_{MAX} = 110 \pm 30^{\circ}C$				- - -	-	-	-
Thermal Shock (Glass Strain)	Method 1056 Cond. A				- - -	-	-	-
Moisture Resistance	Method 1021 Omit Initial Conditioning				- - -	-	-	-
End Points: Collector to Base Current Cutoff	Method 3036 $V_{CBO} = -120Vdc$ , $I_E = 0$				$I_{CBO}$	-	-10	mAdc
Forward Current Trans- fer Ratio	Method 3076 $V_{CE} = -2Vdc$ $I_C = -5Adc$				$h_{FE}$	20	120	-
Collector to Emitter Saturation Voltage	Method 3071 $I_C = -10Adc$ $I_B = -1Adc$				$V_{CE(Sat)}$	-	-0.6	Vdc

1\* Methods referenced are contained in Standard MIL-STD-750

TABLE II  
GROUP B INSPECTION - Continued

EXAMINATION OR TEST	CONDITION	LTPD	MINIMUM REJECTION NUMBER	SYMBOL	LIMITS		UNITS
					MIN.	MAX.	
Subgroup 3 Shock 2,3	Method 2016 Nonoperating 1500 g, 0.5msec 5 blows each in orientations $X_1, X_2, Y_1$ and $Y_2$ (total 20 blows)	10	5	---	--	--	--
Constant Acceleration <sup>2</sup>	Method 2006 10,000 G			---	--	--	--
Vibration Fatigue <sup>2,3</sup>	Method 2046 20 G			---	--	--	--
Vibration Variable Frequency <sup>2,3</sup>	Method 2056 20 G			---	--	--	--
End Points: (Same as for Subgroup 2)							
Subgroup 4 Barometric Pressure Reduced	Method 1001 Pressure=15mmHg t = 60 seconds	20	4	---	--	--	--
End Points: Collector to Base Cutoff Current	Method 3036 VCB = -120Vdc IC = 0			I <sub>CEO</sub>	--	-10	mAdc
High Temperature Operation	T <sub>c</sub> = 85° C			---	--	--	--
Collector to Base Cutoff Current	Method 3036 VCB = -120Vdc IE = 0			I <sub>CBO</sub>	--	-10	mAdc

1° Methods referenced are contained in Standard MIL-STD-750

2° Destructive Tests

3° Non-Operating



Table II  
GROUP B INSPECTION

EXAMINATION OR TEST	CONDITION	LTPD	MINIMUM REJECTION NUMBER	SYMBOL	LIMITS		UNITS
					MIN.	MAX.	
<u>SUBGROUP 5</u> Salt Atmosphere	Method 1041 Cond. B	20	4	----	---	---	----
<u>SUBGROUP 6</u> Thermal Resistance Junction to Case	Method 3126	20	4	----	---	---	----- °C/W
<u>SUBGROUP 7</u> Power Switching Test	See Figure 5 $I_C = 10$ Amps	20	4	----- $\theta_{j-c}$	---	1.2	-----
<u>SUBGROUP 8</u> High Temperature Life (Nonoperating)	Method 1031 $T_A = 110 \pm 10^\circ\text{C}$ - 3	$\lambda = 4$	2	----	---	---	-----
End Points: Collector to Base Cutoff Current	Method 3036 $V_{CB} = -120\text{Vdc}$ $I_E = 0$			ICBO	----	-10	mAdc
Forward Current Transfer Ratio	Method 3076 $V_{CE} = -2\text{Vdc}$ $I_C = -5\text{Adc}$			$h_{FE}$	20	120	----
Collector to Emitter Saturation Voltage	Method 3071 $I_E = -10\text{Adc}$ $I_C = -1\text{Adc}$ $I_B$			$V_{CE(S)}$	---	-0.6	Vdc
<u>SUBGROUP 9</u> Accelerated Life Test High Temperature (Nonoperating)	Method 1031 $T_A = 150^\circ\text{C} \pm 0$ - 3	$\lambda = 10$	5				
End Points: (Same as SUBGROUP 8)							
<u>SUBGROUP 10</u> Operation Life Steady State	$V_{CE} = -24\text{Vdc}$ $P_D = 20\text{W}$ $T_C = 85^\circ\text{C} \pm 0$ - 3	$\lambda = 2.5$	2				
End Points: (Same as for SUBGROUP 8)							

MIL-3-17500/1

# TRANSISTOR OUTLINE TO-41

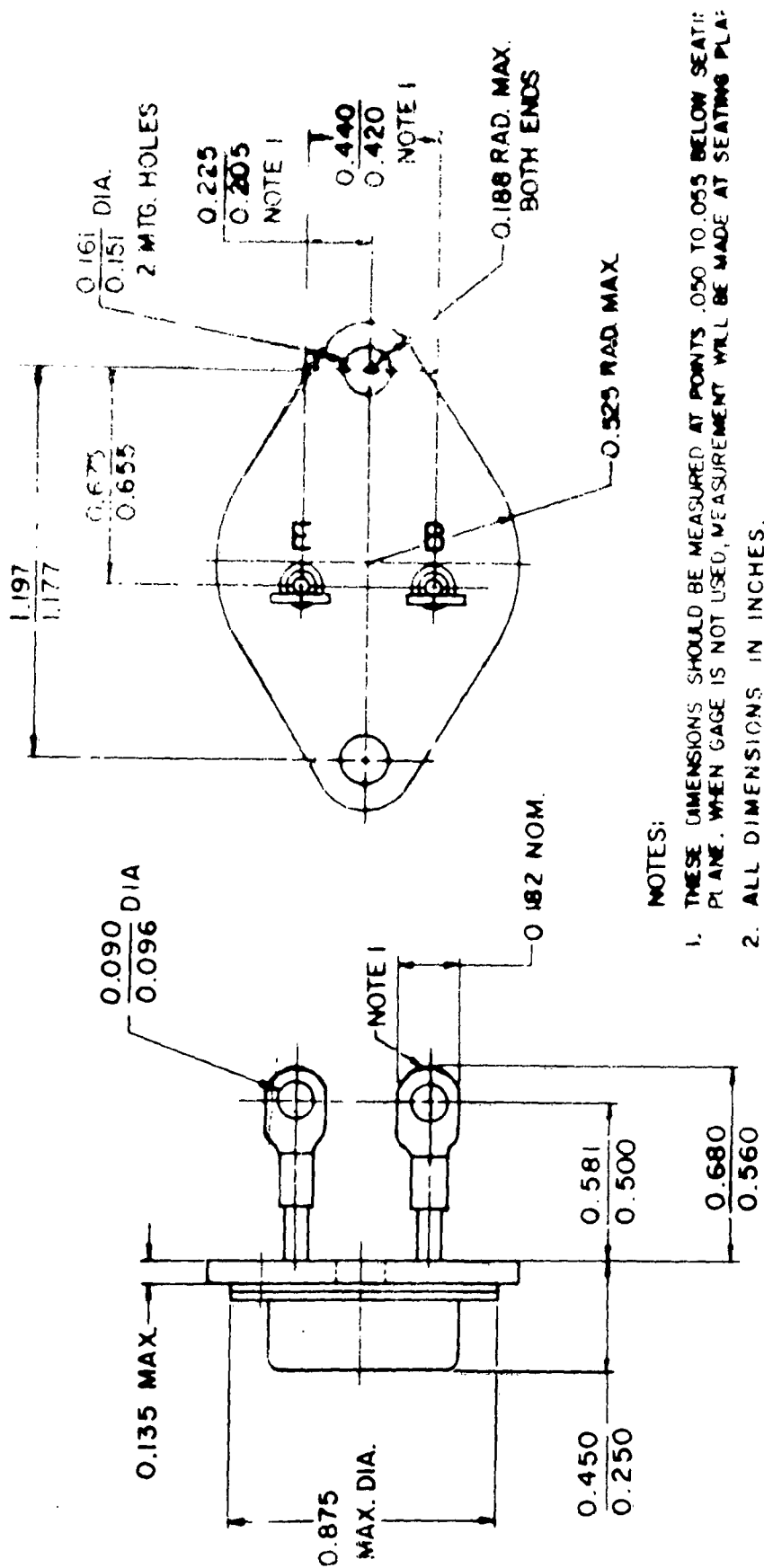


FIGURE 1

MIL-S-19500

RISE, FALL, STORAGE TIME

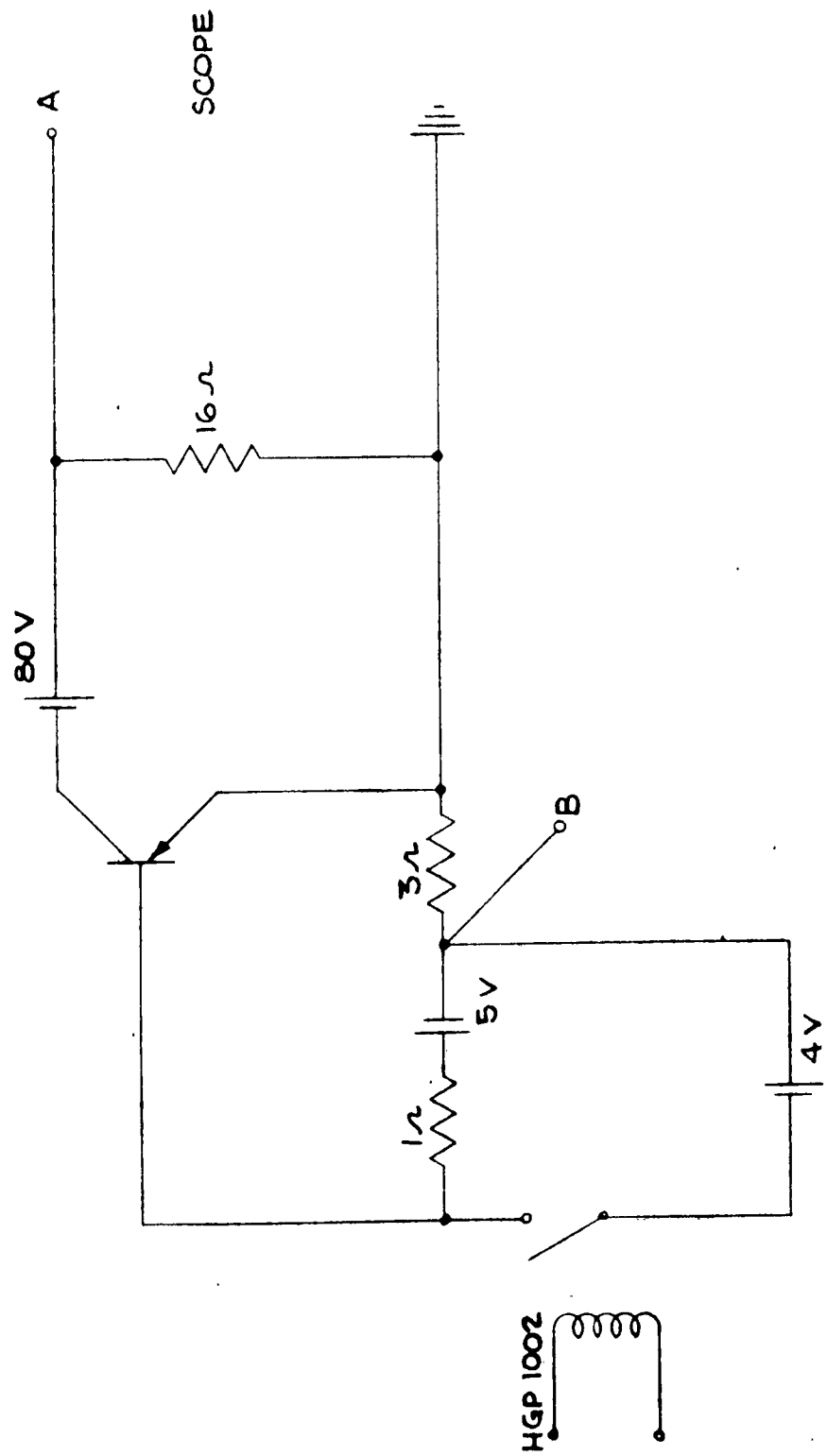


FIG 1

# SAFE OPERATING AREA

2N1430 TEST SPECIFICATIONS  
MIL-S-19500

FOR THE FOLLOWING CONDITIONS:

- 1)  $V|I_B| \leq 1A$
- 2)  $T_j \leq 110^\circ C$
- 3)  $P_T$  (AVERAGE)  $\leq 30W$
- 4) SWITCHING TIME FROM SATURATION TO CUTOFF OR VICE VERSA  $t_s \leq 50 \mu S$
- 5) DRIVING SOURCE OUTPUT RESISTANCE  $R_S \leq 4 \Omega$

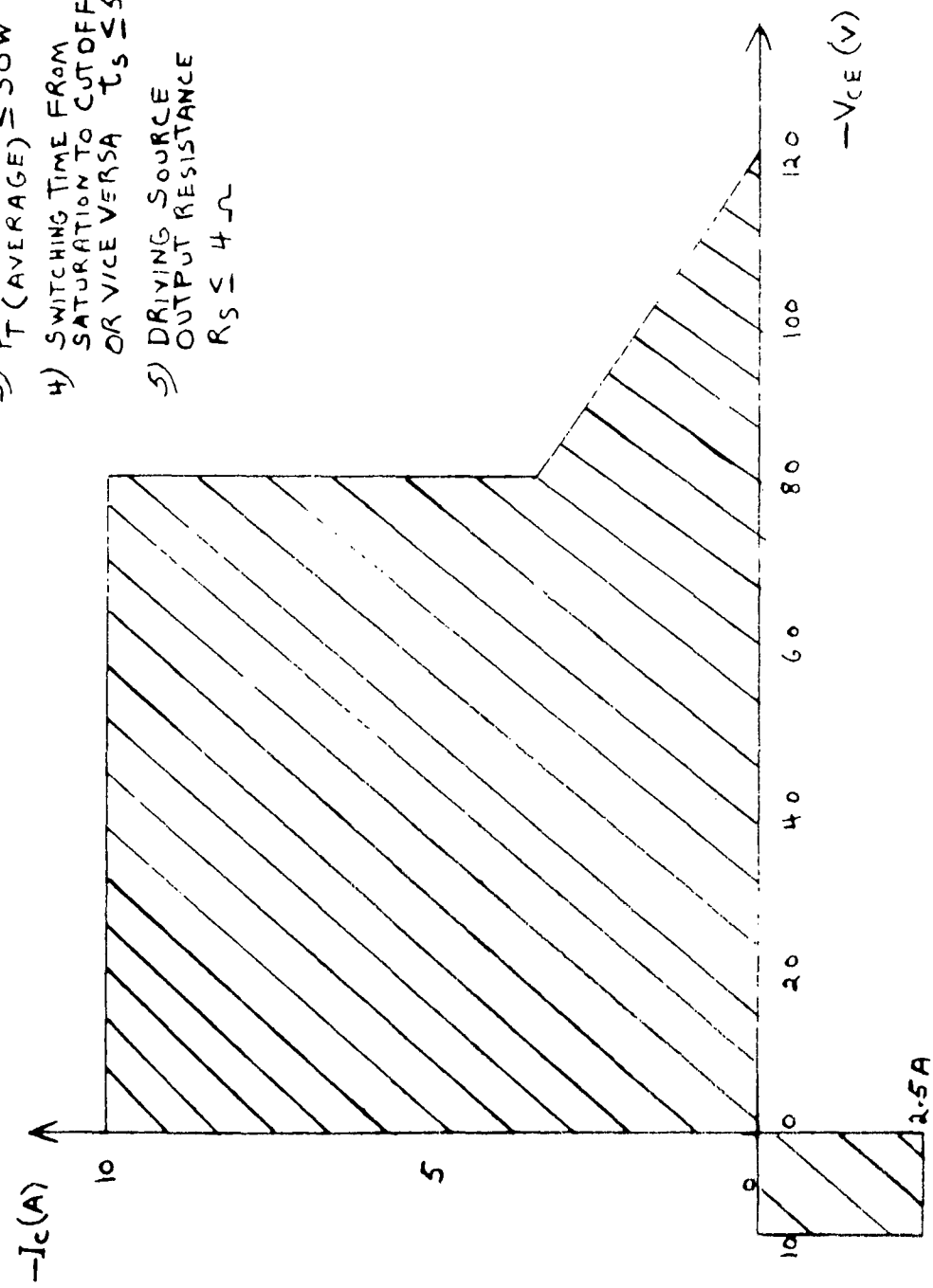


FIG. 3

INDUCTIVE SWEEP TEST

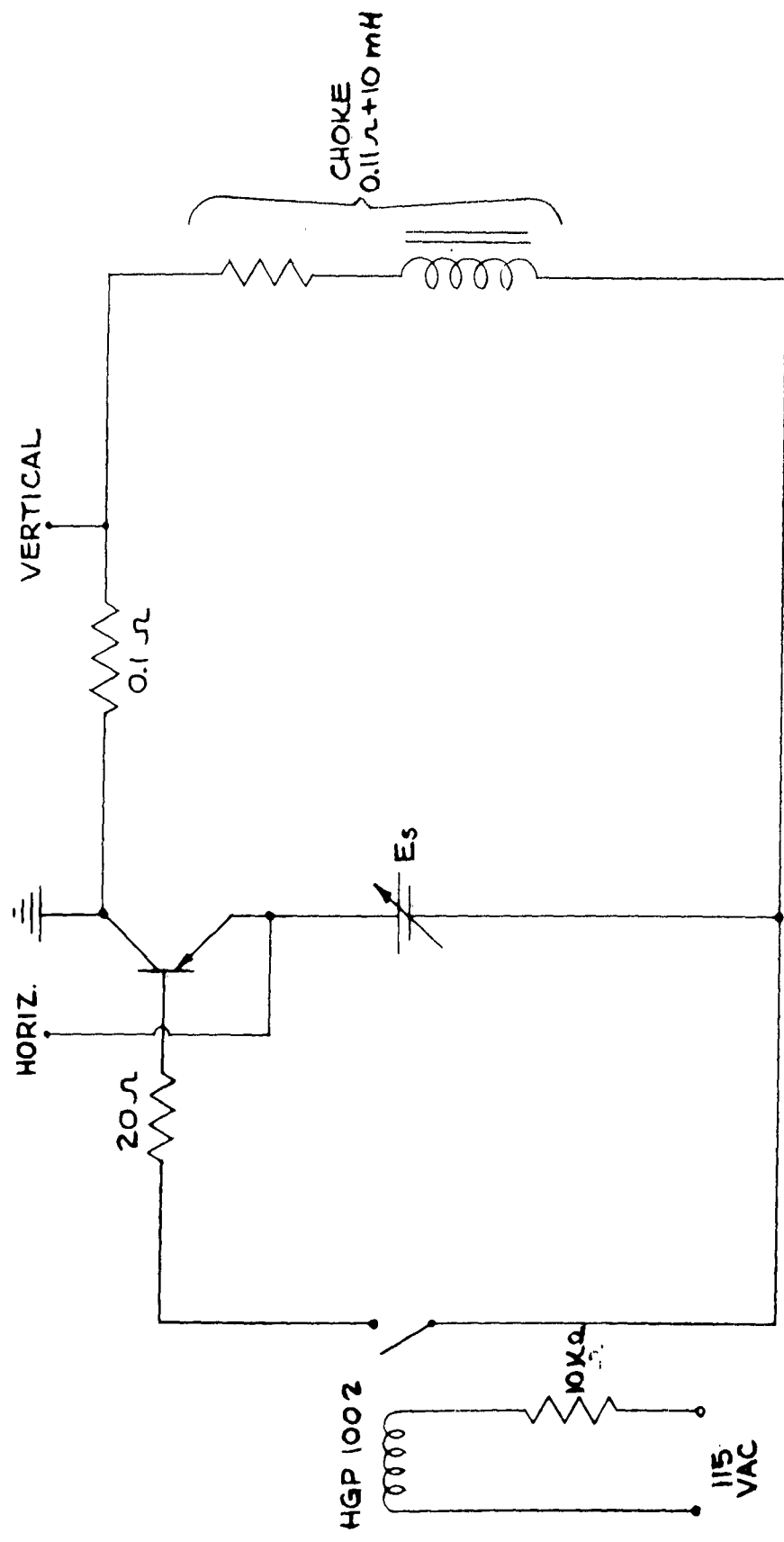
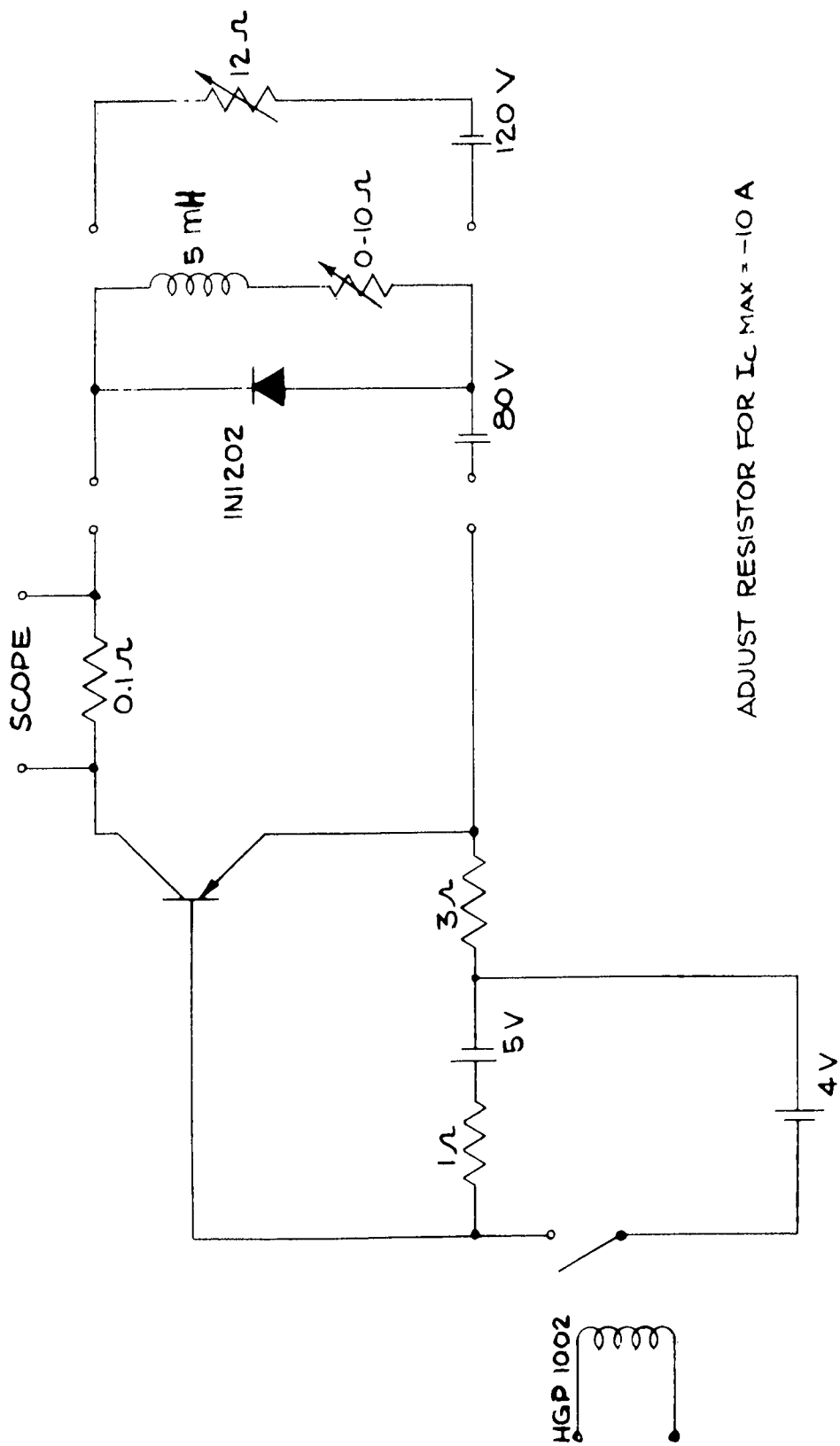


FIG 4

# LOAD LINE SWITCHING TEST



ADJUST RESISTOR FOR  $I_{C\text{ MAX}} = -10\text{ A}$

FIG 5

## IV - APPENDIX I

### PRODUCTION RUN

#### A. General

A production run of 2000 units was made throughout which all of the changes and improvements in processes and in controls recommended as a result of this program were carefully incorporated.

The distributions of several critical parameters were obtained during processing, namely at Mount Check. Later on, after the transistors were aged, 177 units, randomly selected, were tested for all of the parameters listed in the new specification, and the respective distributions were plotted. Note that all of the indicated minima and maxima are in accordance with the tightened specification 2N1450, as submitted in quarterly Report #3. Finally, the entire run was tested on a go-no-go basis to the improved 2N1450 specification.

#### B. Processing Distributions

a) The following distributions are illustrated, at the Mount Testing point:

- 1.- Collector Leakage Current ( $I_{CBO}$ ) [Fig. I - 1]
- 2.- Base Current ( $I_B$ ) [Fig. I - 2]
- 3.- Collector-to-Emitter Voltage ( $BV_{CEB}$ ) [Fig. I - 3]

b) Discussion of the Distributions

1.- The collector leakage current at  $V_{CB}=2$  Volts shows a very well behaved pattern and a small standard deviation. This indicates a good control on resistivity. The achieved average is better than the objective.

2.- The base current histogram shows a distribution slight skewed to the right, but otherwise satisfactory. The target for the standard deviation was essentially met, while the average is somewhat short of the goal. This is not of major consequence since the  $I_B$  tends to become larger during the aging process.

3.- The collector-to-emitter voltage appears to have a distribution slightly skewed to the left. The average achieved is far in excess of the objective. This is so because the original target was established on the basis of the old specification [ $I_{CEO}$  at 40 V with maximum  $I_C = .1A$ ]. Later on the tightened specification was proposed in which  $BV_{CEO}$  at .1A with minimum 100V had to be met. This requires a much higher  $BV_{CEB}$ .

#### C. Raw (Unscreened) After-Aging Distributions

a) The following distributions are presented

- 1.- Collector Cutoff Current ( $I_{CBO}$ ,  $V_{CB} = 2V$ ) [Fig. I - 4]
- 2.- Collector Cutoff Current ( $I_{CBO}$ ,  $V_{CB} = 120V$ ) [Fig. I - 5]
- 3.- Collector Cutoff Current ( $I_{CBO}$ , High Temperature) [Fig. I - 6]
- 4.- Collector Cutoff Current ( $I_{CES}$ ) [Fig. I - 7]
- 5.- Base Current ( $V_{CE} = 2V$ ,  $I_C = 10A$ ) [Fig. I - 8]

- 6.- Base Current ( $V_{CE}=2V$ ,  $I_C=5A$ ) [Fig. I - 9]
- 7.- Collector Saturation Voltage ( $V_{CE}(S)$ ) [Fig. I - 10]
- 8.- Saturation Voltage ( $V_{BE}(S)$ ) [Fig. I - 11]
- 9.- Collector Emitter Breakdown ( $BV_{CEO}$ , Full Wave) [Fig. I - 12]
- 10.- Collector Emitter Breakdown ( $BV_{CEO}$ , Inductive Sweep) [Fig. I - 13]
- 11.- Emitter to Base Breakdown ( $BV_{EB0}$ ) [Fig. I - 14]
- 12.- Rise Time [Fig. I - 15]
- 13.- Fall Time [Fig. I - 16]
- 14.- Storage Time [Fig. I - 17]
- 15.- Thermal Resistance [Fig. I - 18]

b) Discussion of the Distributions

It is to be emphasized here that all the minimum and maximum limits plotted are based on the tightened newly proposed 2N1430 specification.

1.- Fig. I - 4 shows an extremely well behaved distribution well within the maximum specified.

2.- Fig. I - 5 shows a slightly skewed distribution, well within the maximum.

3.- Fig. I - 6 illustrates a very well behaved distribution far under the maximum limit.

4.- Fig. I - 7 indicates a skewed distribution, however it is well removed from the maximum.

5.- Fig. I - 8 is generally well behaved with a slight skewness. About 91% of the product is within the minimum and maximum limits.

6.- Fig. I - 9 shows a distribution similar to Fig. I - 8, except that here 96% of the product meets the specification.

7.- Fig. I - 10 appears to exhibit a double distribution. Even so, better than 93% of the population is within specification.

8.- Fig. I - 11 is a very sharp distribution where 96% of the product meets the specification.

9.- Fig. I - 12 is a well behaved distribution where 94% is within the old specification and 82% within the tightened specification.

10.- Fig. I - 13 is a sharp distribution with about 75% of the product meeting the specification.

11.- Fig. I - 14 is slightly skewed to the right, however the distribution is far removed from the minimum specified.

12.- 13.- 14.- Fig. I - 15, 16 and 17 are extremely well behaved and very comfortably within specifications.

15.- Fig. I - 18 is well behaved, but not quite sharp enough. Eighty-nine per cent meets specification.

In general, this production run has shown very satisfactory results.

CAUTION: If one were to calculate an overall yield on the basis of the above indicated percentages, one would obtain a very pessimistic yield, rather than a realistic one.



This is due to the fact that in many cases one unit showing a characteristic outside of specification on one parameter often will be out of specification on other parameters as well, so that it is one unit reduces the yield on every parameter, rather than just be counted only once as a defective unit.

D. Yield

The units were screened first to the old 2N1430 specification. Subsequently they were recombined and screened again, this time to the tightened 2N1430 specification. The results are shown below.

YIELD

	Before inception of program	Proposed, based on old 2N1430 Specification	Achieved on the basis of	
			old 2N1430 Specification	Tightened 2N1430 Specification
Element Test	82%	95%	89%	89%
Mount Test	90%	95%	93%	93%
Finished Product	50%	75%	81%	70%
Overall	38%	68%	67%	58%

FIGURE I-1

2N 1430

MOUNT TEST

SIGNAL CORPS SPECIAL

$I_{CB0} @ V_{CB} = -2V_{dc}$

OBJECTIVE

AT

INCEPTION

OF

PROGRAM

$\bar{x}$

$\sigma$

62  $\mu A$

15  $\mu A$

ACTUALLY

ACHIEVED

57  $\mu A$

15  $\mu A$

RELATIVE FREQUENCY, %

30

20

10

0

30 40 50 60 70 80 90 100

$\mu A_{dc}$

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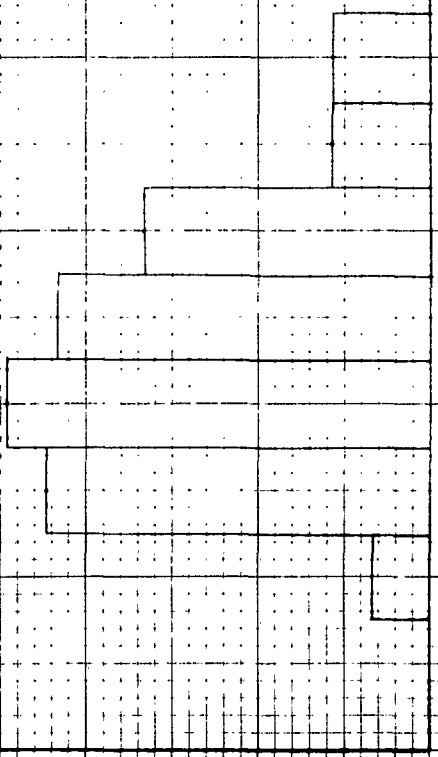


FIGURE I-2

2N 1430

MOUNT TEST

SIGNAL CORPS SPECIAL

$I_B @ V_{CE} = -2V_{dc}$   
 $I_C = -5A_{dc}$

OBJECTIVE  
 AT  
 INCEPTION  
 OF  
 PROGRAM

ACTUALLY  
 ACHIEVED

$\bar{X}$

$\sigma$

114 mA

100 mA

32 mA

34 mA

RELATIVE FREQUENCY, %

30

20

10

0

45 60 75 90 105 120 135 150 165 180

$mA_{dc}$

FRA 5/63

FIGURE I-3

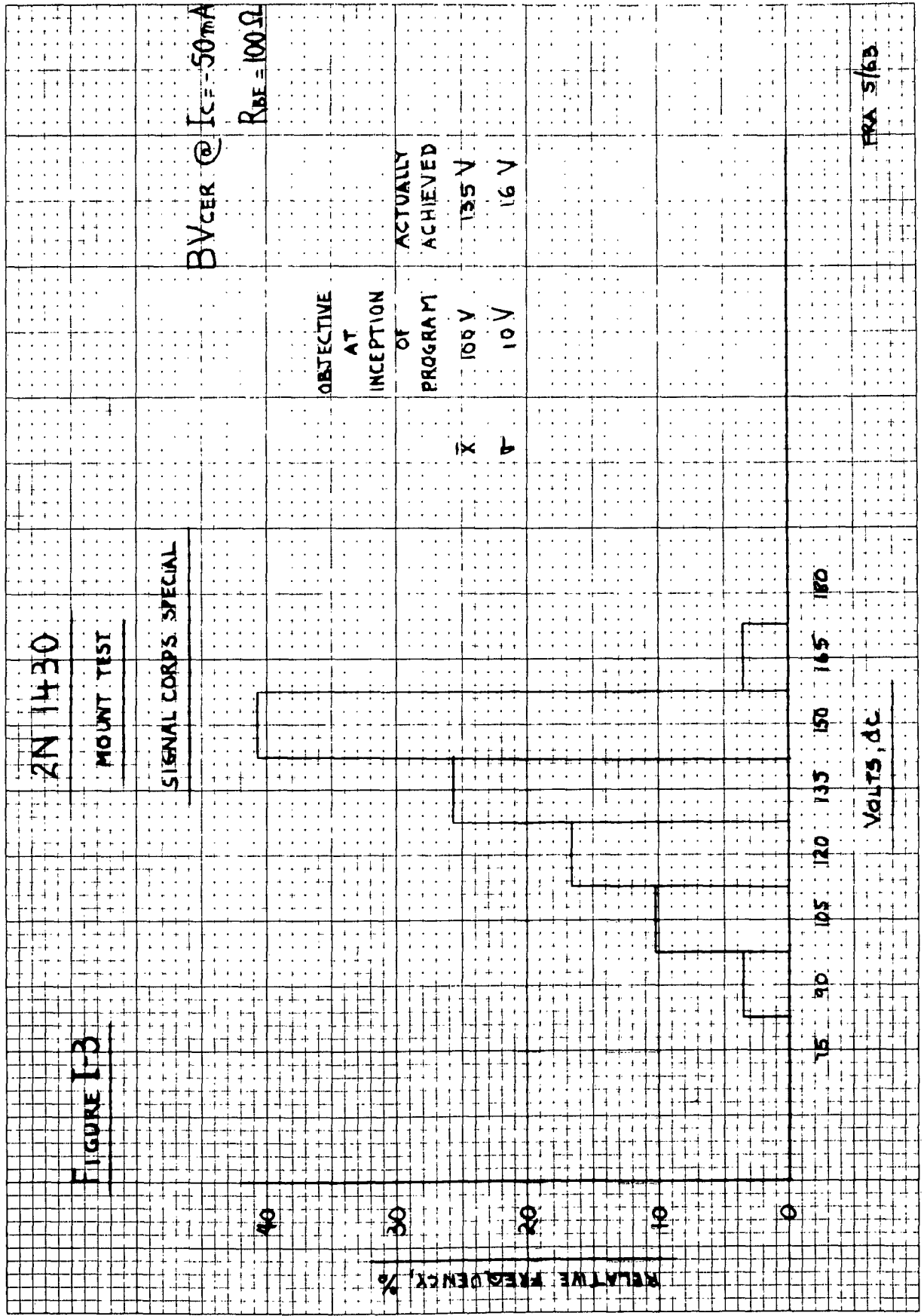


FIGURE 1-4

2N 1430

AFTER AGING: RAW DISTRIBUTION

SIGNAL CORPS SPECIAL

$I_{CBO} @ V_{CB} = -2V_{dc}$

$\bar{x} = 60 \mu A_{dc}$

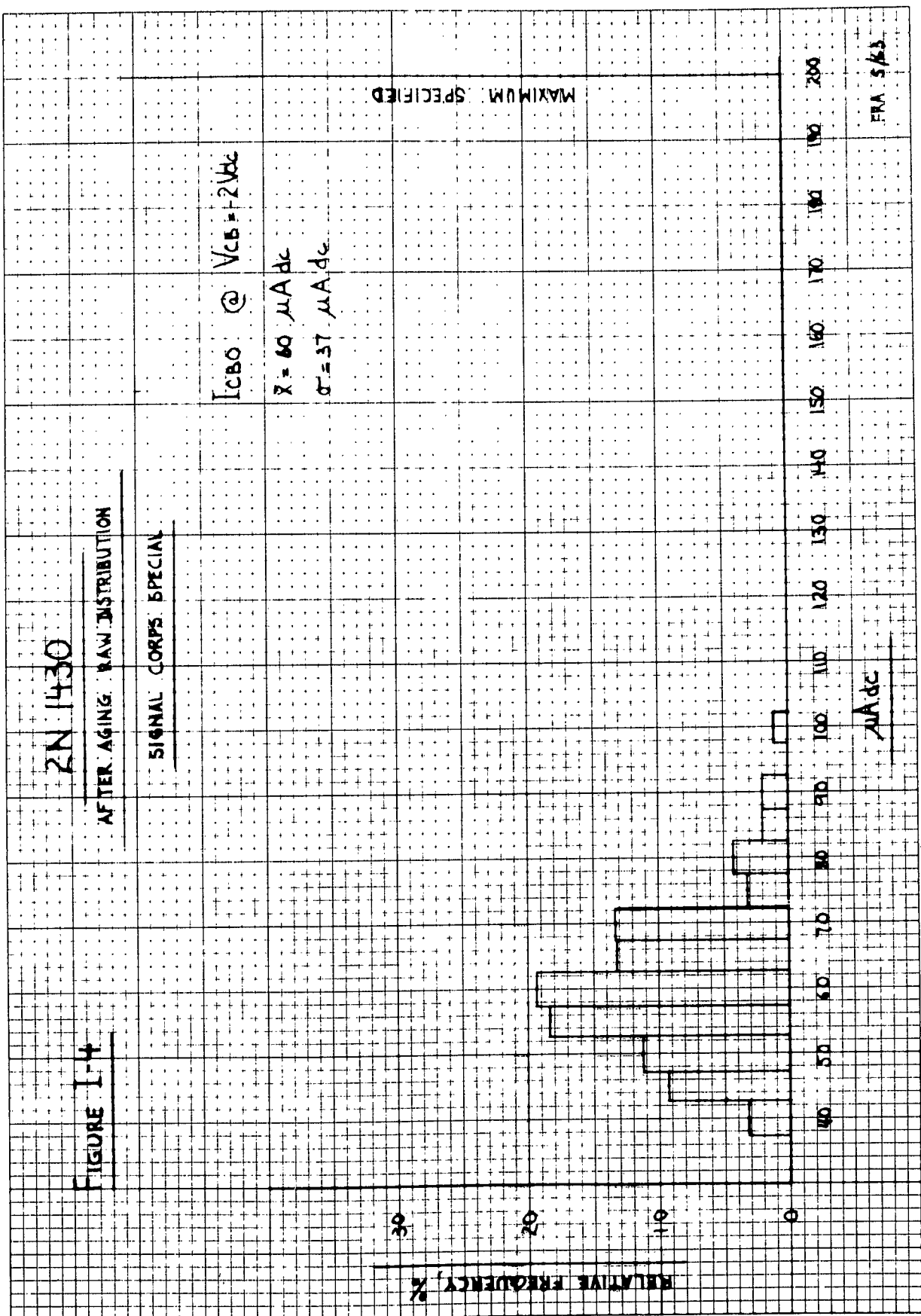
$\sigma = 37 \mu A_{dc}$

MAXIMUM SPECIFIED

RELATIVE FREQUENCY, %

$\mu A_{dc}$

FRA 5/63



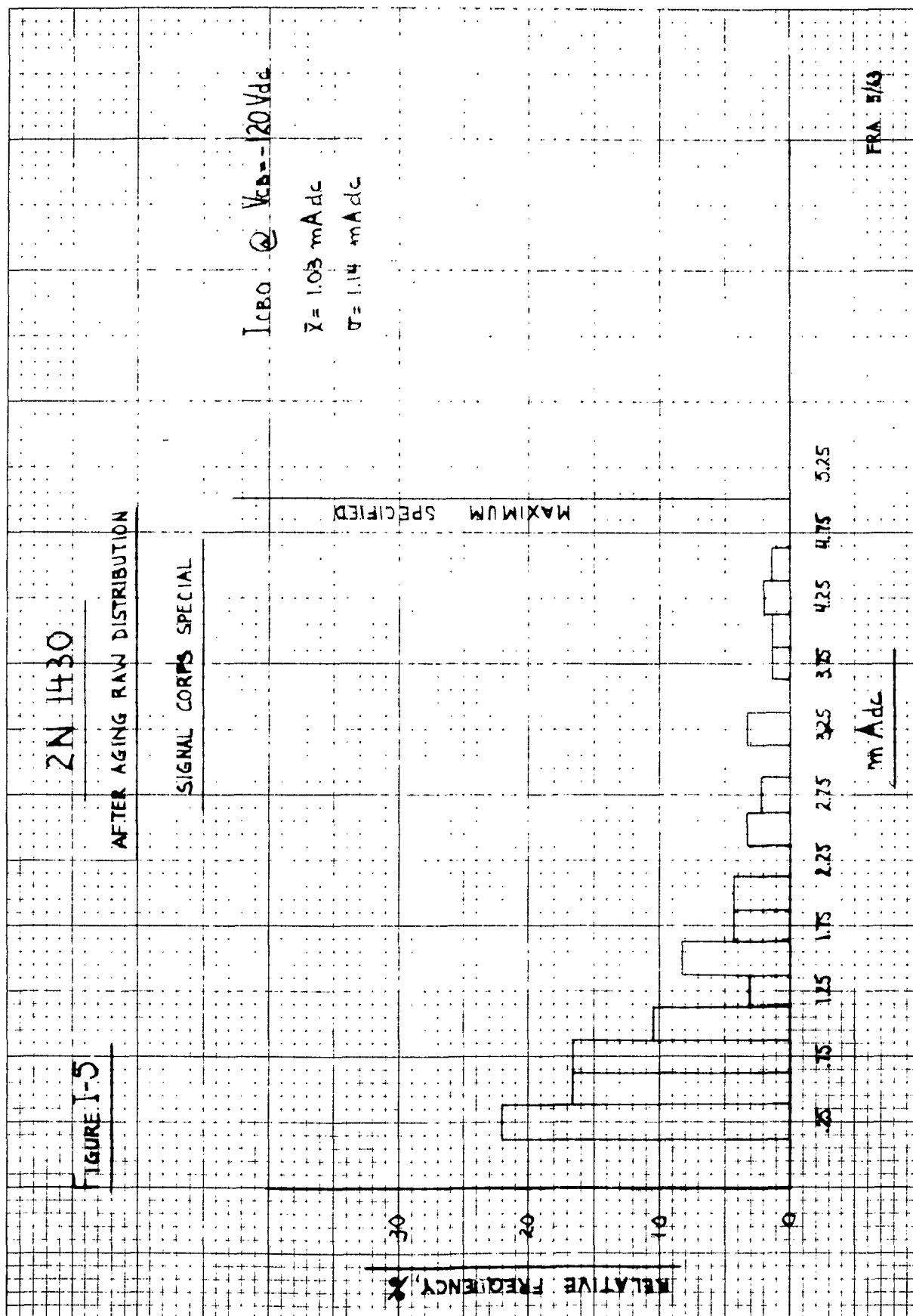


FIGURE 1-6

2N 1430

AFTER AGING RAW DISTRIBUTION

SIGNAL CORPS SPECIAL

$I_{CBO} @ 85^{\circ}C$   
 $V_{CB} = 100V_{dc}$

$\bar{x} = 3.2 mA_{dc}$

$\sigma = 1.2 mA_{dc}$

MAXIMUM SPECIFIED

RELATIVE FREQUENCY, %

1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

$mA_{dc}$

FNA 5/63

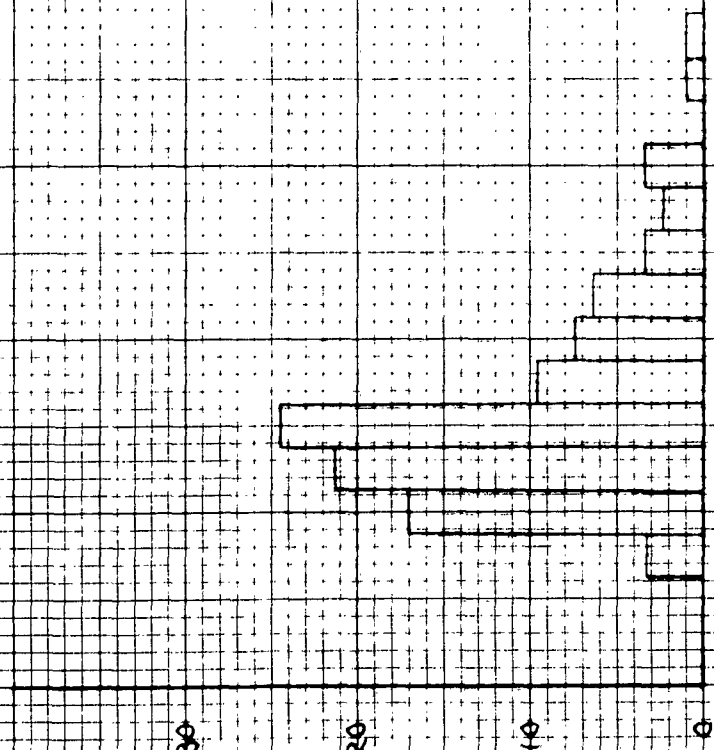
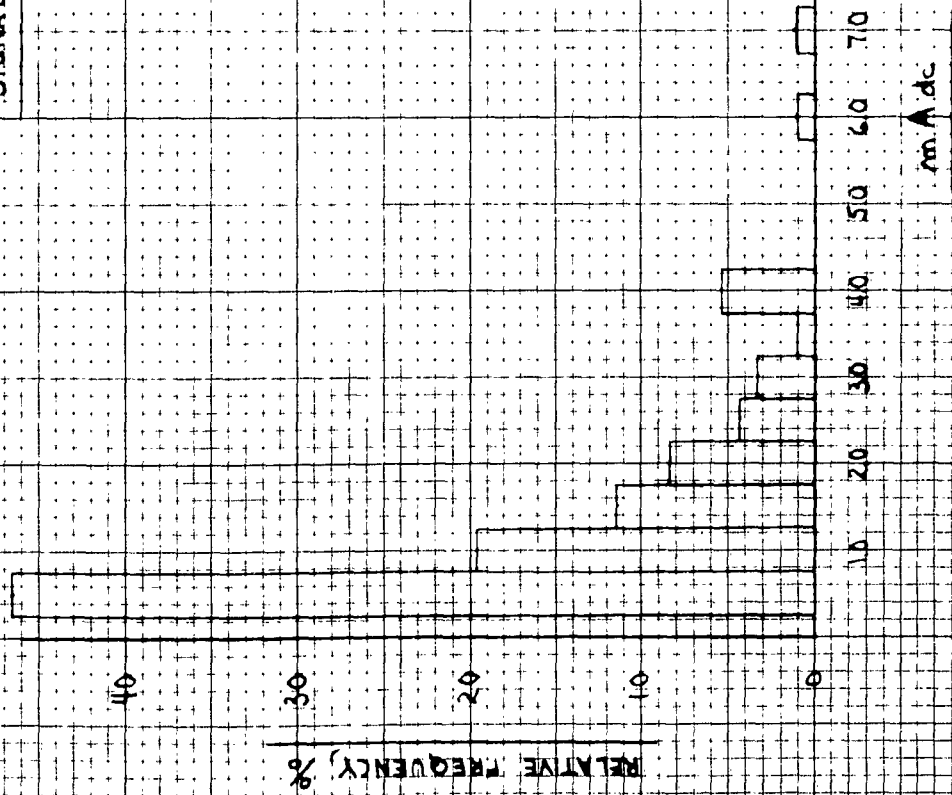


FIGURE 1-7

2N 1430

AFTER AGING RAW DISTRIBUTION  
SIGNAL CORPS SPECIAL



$I_{CES}$  @  $V_{CE} = -120 V_{dc}$

$R_{BE} = 0 \Omega$

$\bar{I} = 12 mA_{dc}$

$\sigma = 1.0 mA_{dc}$

FRA 5/63



FIGURE 1-8

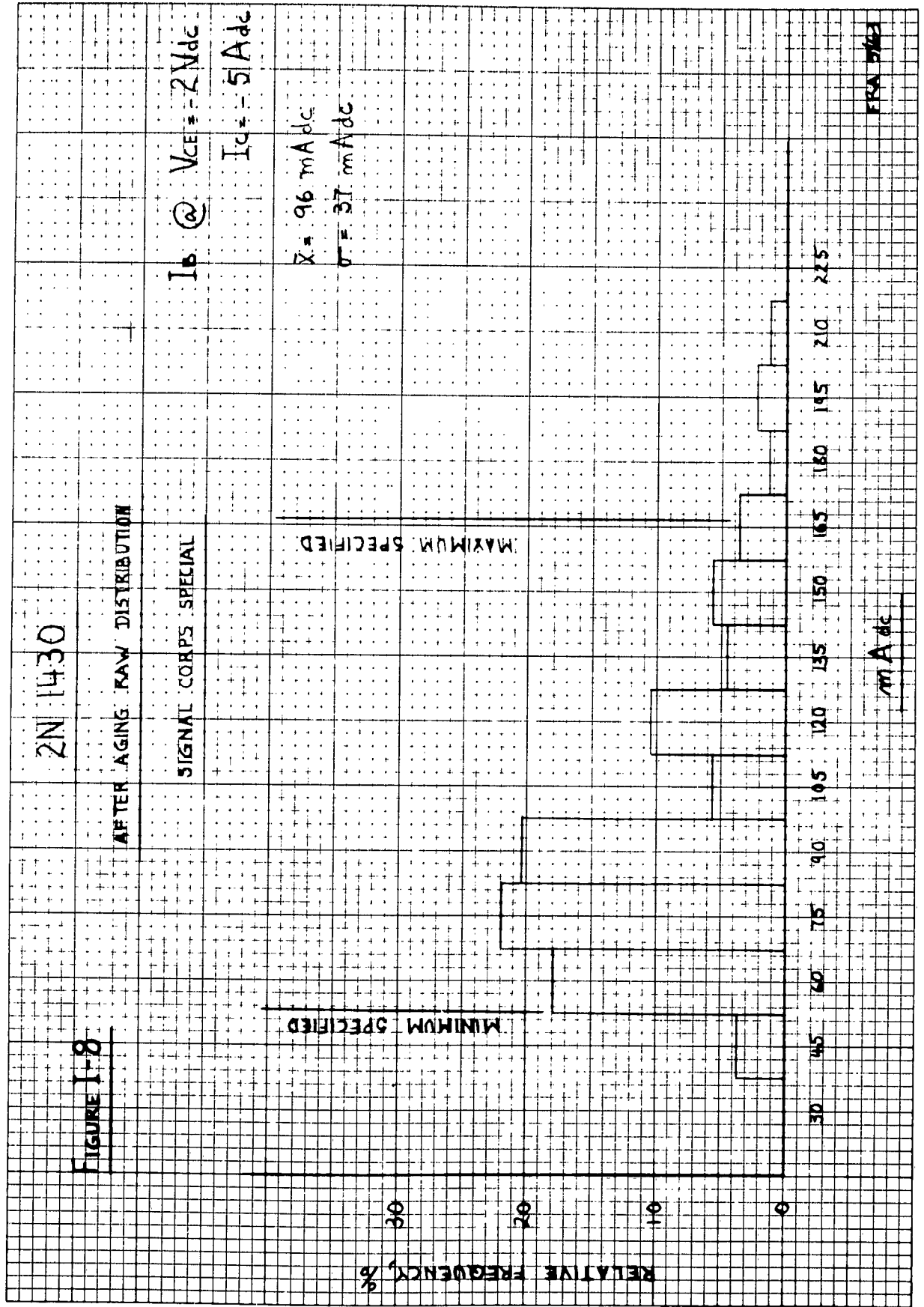


FIGURE 1-9

2N 1430

AFTER AGING RAW DISTRIBUTION

SIGNAL CORPS SPECIAL

$I_B @ V_{CE} = -2 V_{dc}$

$I_C = -10 A_{dc}$

$\bar{X} = 228 mAdc$

$\sigma = 128 mAdc$

MAXIMUM SPECIFIED

RELATIVE FREQUENCY, %

$mAdc$

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75 125 175 225 275 325 375 425 475 525 575 625 675 725

FIGURE 1-10

2N 1430

AFTER AGING RAW DISTRIBUTION

SIGNAL CORPS SPECIAL

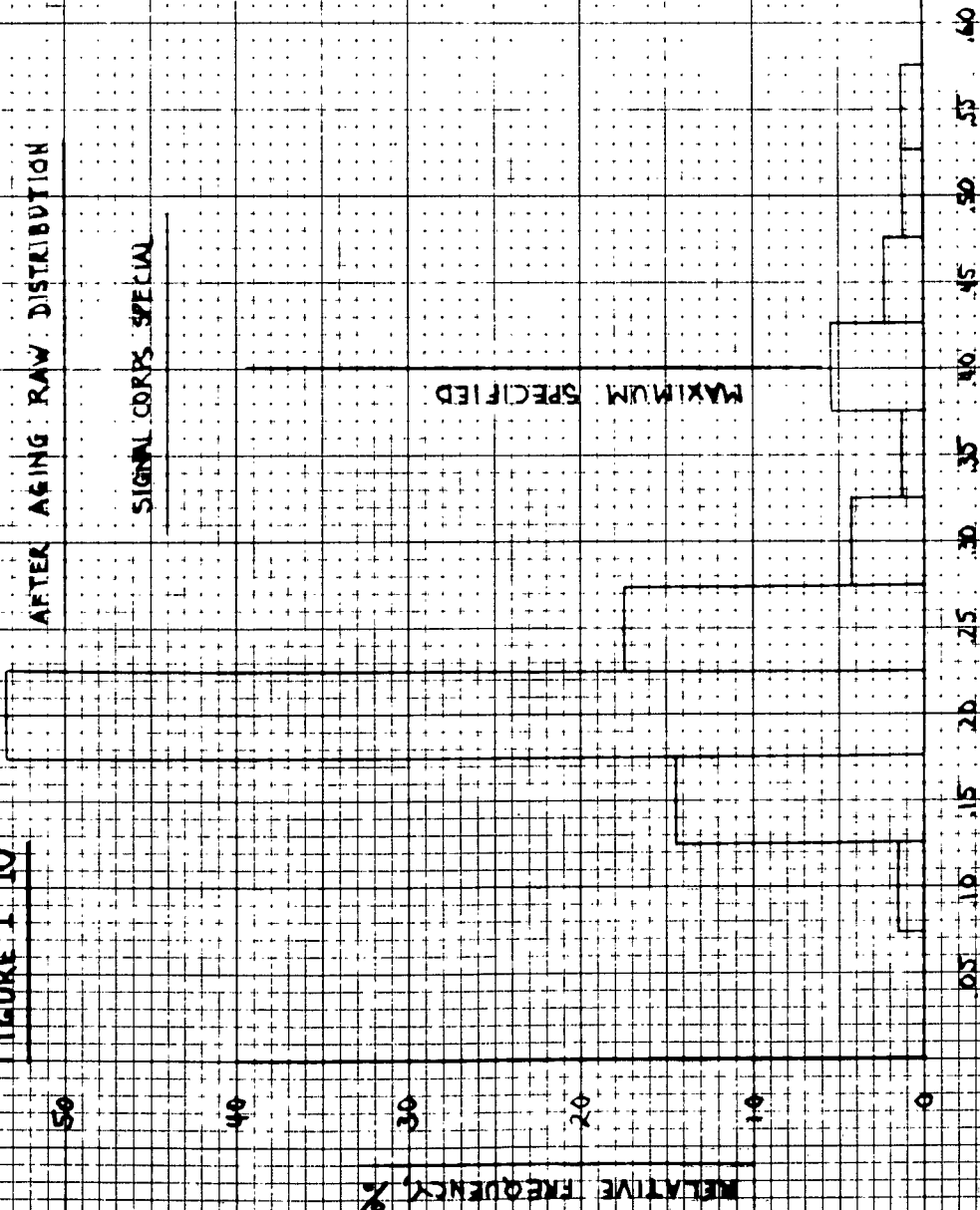
$V_{CE}(s)$  @  $I_C = -10A_{dc}$

$I_B = -1000mA_{dc}$

$\bar{x} = .25 V_{dc}$

$\sigma = .11 V_{dc}$

MAXIMUM SPECIFIED



VOLTS dc

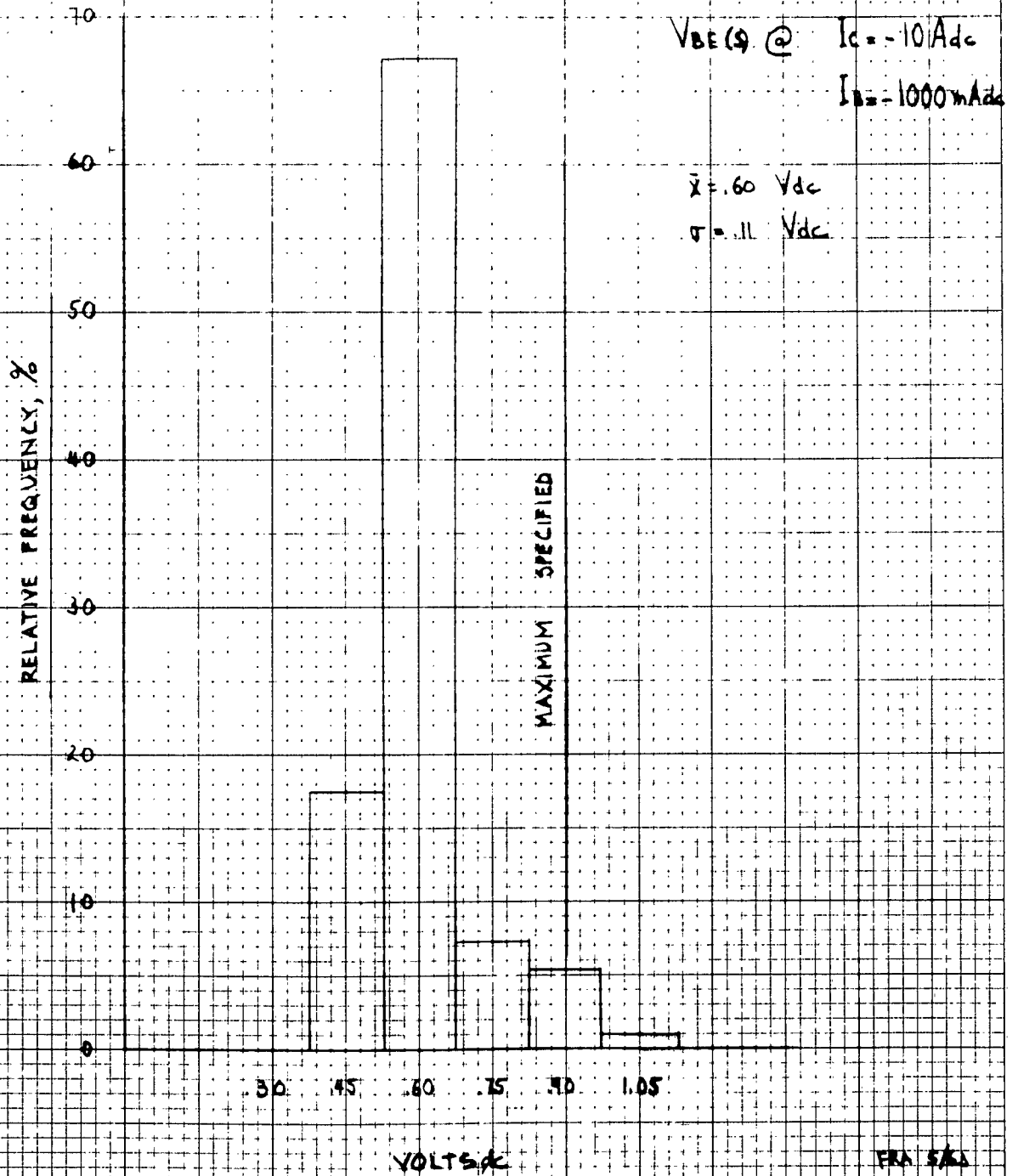
FRA 5/63

2N 1430

AFTER AGING RAW DISTRIBUTION

FIGURE I-II

SIGNAL CORPS SPECIAL



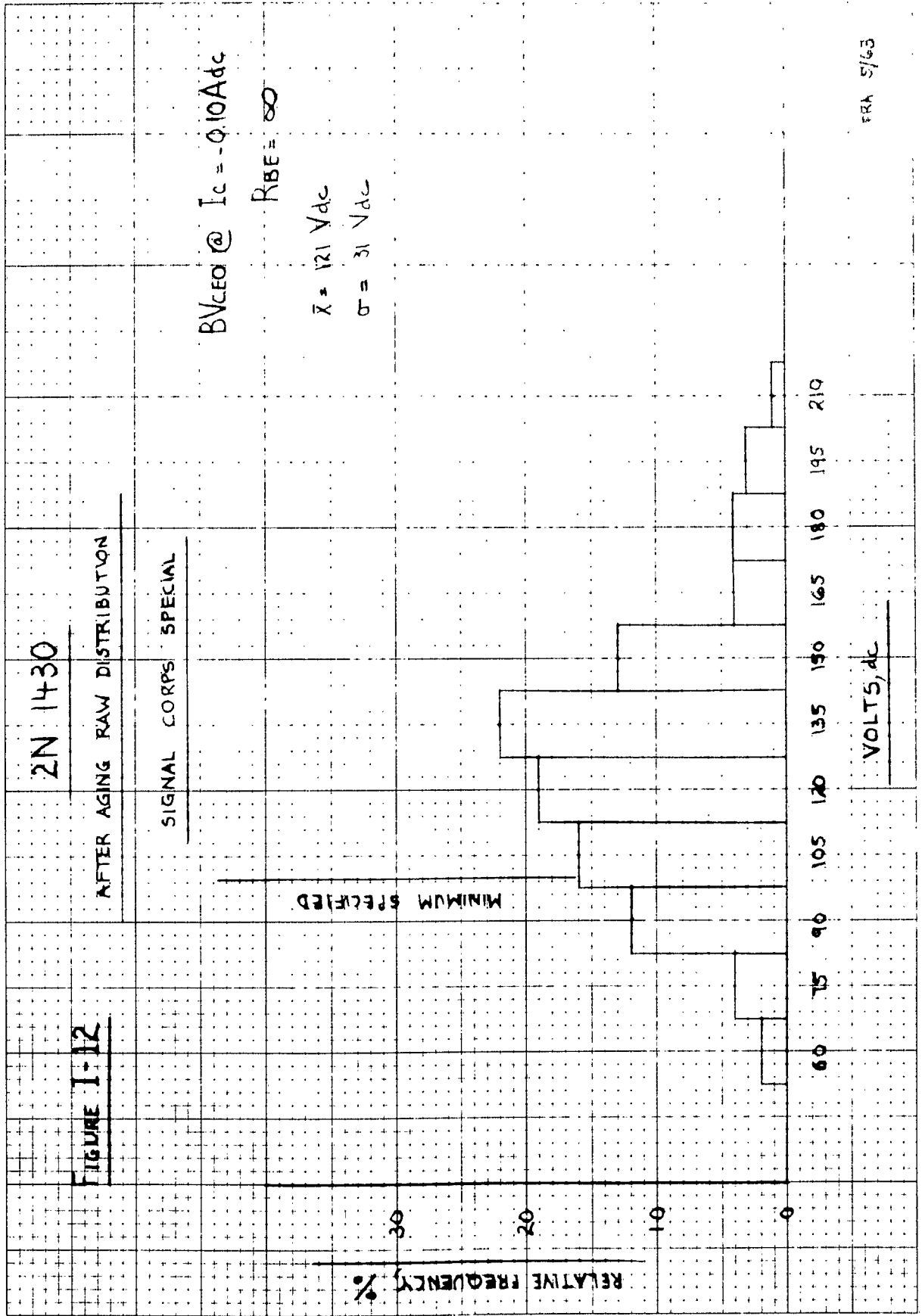


FIGURE 1-13

2N 1430

AFTER AGING RAW DISTRIBUTION

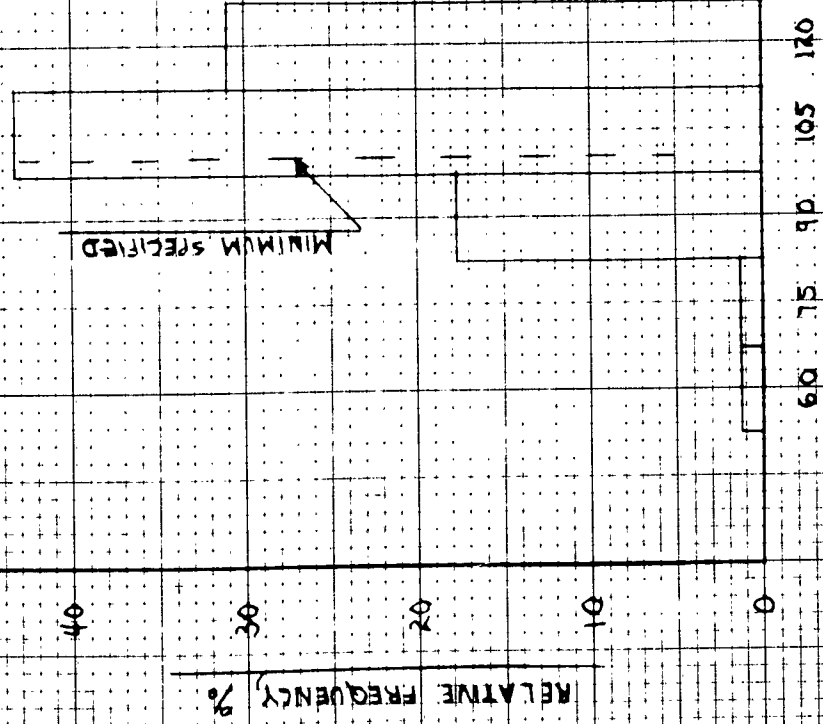
SIGNAL CORPS SPECIAL

BV<sub>CEO</sub> [INDUCTIVE SWEEP]

$I_C = -2.0 \text{ A dc}$

$\bar{X} = 108 \text{ V dc}$

$\sigma = 13 \text{ V dc}$



VOLTS dc

FRA 5/63

FIGURE I-14

2N 1430

AFTER AGING RAW DISTRIBUTION

SIGNAL CORPS SPECIAL

BVEBO @ 50 mA<sub>dc</sub>

$$\bar{X} = 4.7 \text{ V}_{dc}$$

$$\sigma = 1.1 \text{ V}_{dc}$$

RELATIVE FREQUENCY %

MINIMUM SPECIFIED

1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0

VOLTS<sub>dc</sub>

FRA 5/63

30 20 10 0

FIGURE 1-15

2N 1430

AFTER AGING RAW DISTRIBUTION

SIGNAL CORPS SPECIAL

SWITCHING TEST

@  $V_{CE} = 80V$   
 $I_C = 5A$

RISE TIME

$\bar{x} = 4.5 \mu s$   
 $\sigma = 0.6 \mu s$

MAXIMUM SPECIFIED

RELATIVE FREQUENCY, %

$\mu s$

TRA 563

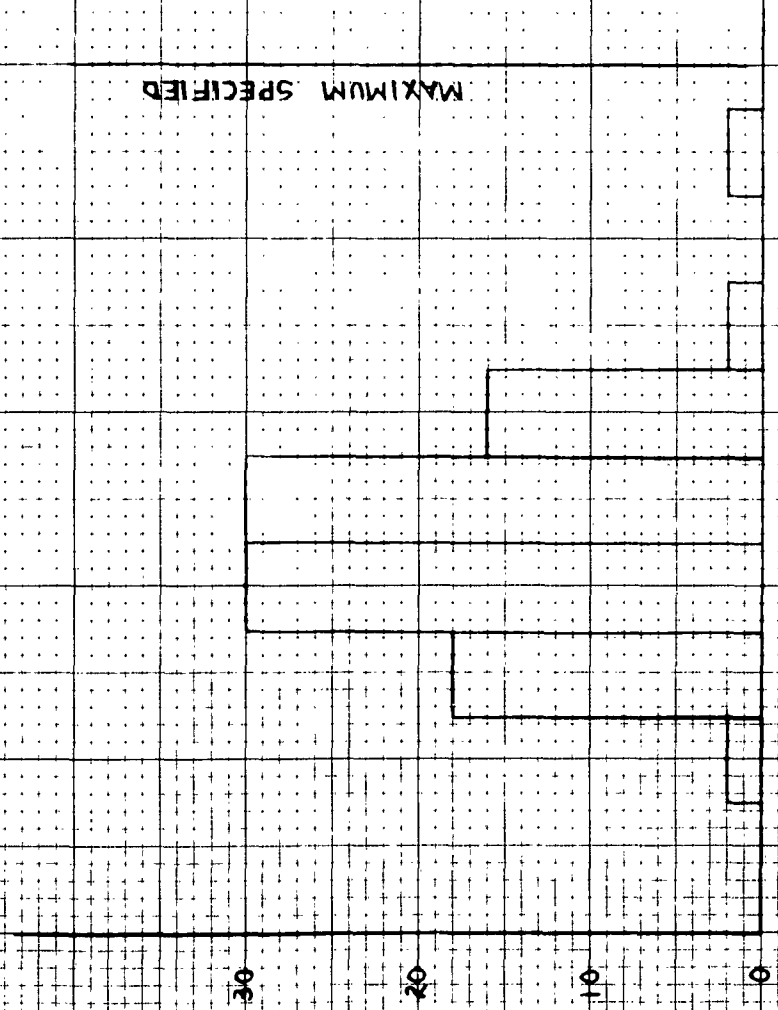




FIGURE I-16

2N 1430

AFTER AGING RAW DISTRIBUTION

SIGNAL CORPS SPECIAL

SWITCHING TEST

@  $V_{CE} = 80V$

$I_C = 5A$

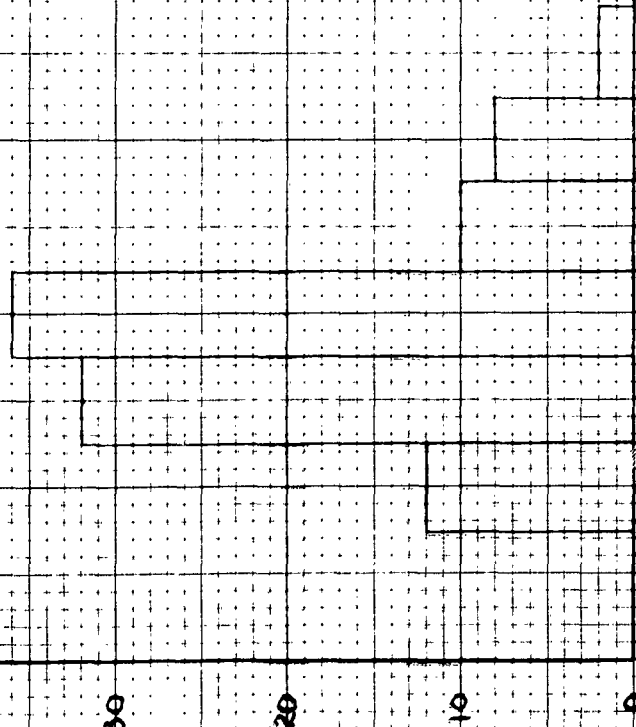
FALL TIME

$\bar{x} = 2.1 \mu s$

$\sigma = 0.58 \mu s$

MAXIMUM SPECIFIED

RELATIVE FREQUENCY, %



$\mu s$

FIG. 1-16

FIGURE 1-17

2N 1430

AFTER AGING RAW DISTRIBUTION

SIGNAL CORPS SPECIAL

SWITCHING TEST

$V_{CE} = 90V$

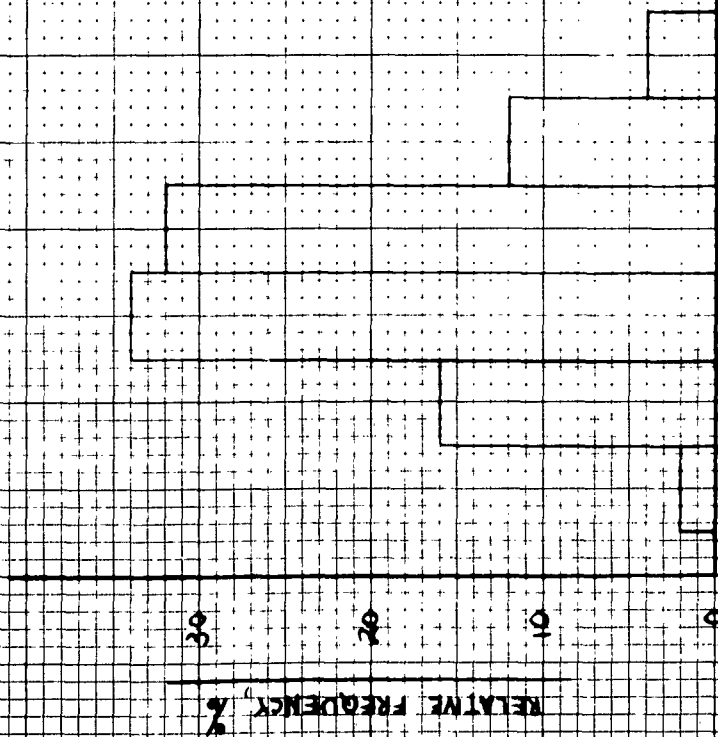
$I_{C2} = 5A$

STORAGE TIME

$\bar{x} = 1.8 \mu S$

$\sigma = 0.2 \mu S$

MAXIMUM SPECIFIED



FRA 5/63

FIGURE 1-18

2N 1430

AFTER AGING RAW DISTRIBUTION

SIGNAL CORPS SPECIAL

THERMAL RESISTANCE

$$\bar{r} = 1.04 \text{ } ^\circ\text{C/W}$$

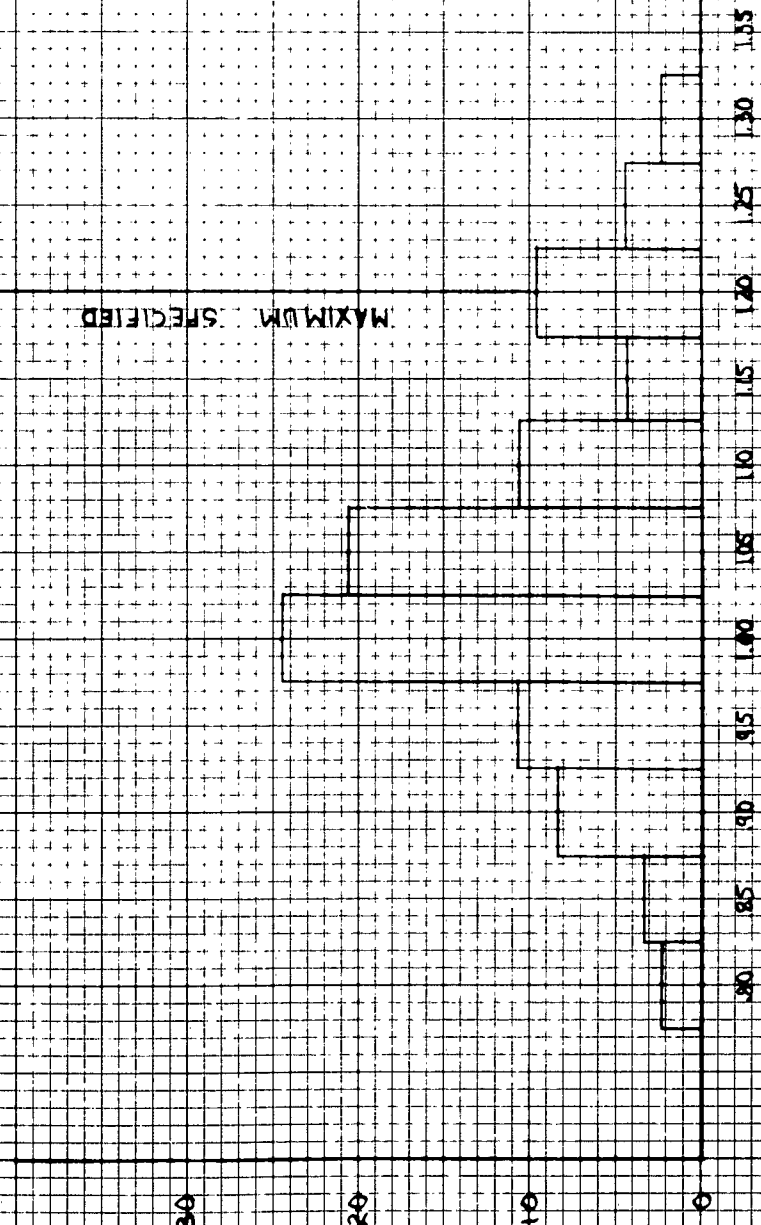
$$s_r = 0.11 \text{ } ^\circ\text{C/W}$$

MAXIMUM SPECIFIED

RELATIVE FREQUENCY, %

$^\circ\text{C/W}$

FRA 543



#### IV - APPENDIX II

##### 1.0 Reliability Determination

The remainder of the Production Reliability Engineering Measure will consist primarily of an evaluation of a production lot of approximately 100 transistors. This lot is manufactured under stringent lot control conditions and incorporates all of the product improvements resulting from the subject 2N1430 Engineering Measure.

The most important phase of the final evaluation will be an accelerated life test program designed to provide information reflecting an objective failure rate of 0.05% per 1000 hours at 25°C. Actual testing will be conducted over a period of 2500 hours. Sample sizes are determined in accordance with the following expression:

$$n \leq \frac{F+1}{\lambda t_e} \cdot F + r$$

The above equation and resultant table of unit - hours required to demonstrate  $\lambda \leq 0.05\%/1000$  hours is shown as equation (3) and Table 2 of this Appendix.

Results of the accelerated life test program will be based on a minimum of 60,000 unit hours at the maximum stress and 75,000 unit hours at the minimum stress.

The comprehensive reliability program plan, in addition to describing the behavior of the Bendix 2N1430 transistor at accelerated temperature conditions will also include an accelerated operating power life test program to be run in parallel with the accelerated temperature tests. The accelerated power life tests will be conducted at operating conditions which are calculated to reflect an acceleration factor of 1.5 times the acceleration factor of high temperature testing. This figure is based on engineering investigation which considers both the effect of high current densities and any localized heating.

It should be noted that the Reliability Determination will be based on accelerated life tests that are conducted in terms of single levels of acceleration, i.e., the total sample will be subdivided into five (5) subgroups and tested in accordance with acceleration factors calculated to reflect the objective failure rate of 0.05% per 1000 hours at 25°C. The intent here is to generate parameter information which is unbiased by the effects of previous step stress fatigue.

##### 2.0 Data Analysis

The measure of failure rates resulting from the Reliability Determination program will be evaluated at various intervals while the program progresses. A final determination and report summation will be prepared at the conclusion of all tests. Implementation of the Reliability Determination will be in accordance with the statistical techniques described in Paragraphs 5.0 through 6.0 of this Appendix.

#### IV - APPENDIX II

##### 3.0 Program Plan

Appendix III describes the Reliability Determination portion of the 2N1430 Production Engineering Measure in flow chart form.

##### 4.0 Program Schedule

Appendix IV describes the schedule plan applicable to the Reliability Determination Plan.

#### IV - APPENDIX II

##### 5.0 Failure Rate Study:

To obtain an estimate of failure rates in a reasonable amount of time with a reasonable number of units, accelerated life tests shall be applied.

In general, a point-estimate of the failure rate, assuming an exponential distribution, may be obtained as:

$$\lambda = \frac{\ln \left[ \frac{n}{n-r} \right]}{t} \quad (1)$$

where:  $\lambda$  = failure rate  
 $\ln \lambda$  = natural logarithm of  $\lambda$   
 $n$  = number of units on test  
 $r$  = number of failures  
 $t$  = duration of test

A one-sided confidence limit for  $\lambda$  is:

$$\lambda < \frac{\ln \left[ 1 + \frac{(r+1)}{(n-r)} F_{\alpha}(2r+2, 2n-2r) \right]}{t} \quad (2)$$

where all symbols have been previously defined except that:

with  $F_{\alpha}(2r+2, 2n-2r)$  refers to the F distribution  
 $\alpha$  = confidence  
 $2r+2$  = degrees of freedom in the numerator  
 $2n-2r$  = degrees of freedom in the denominator

The acceleration factors of the failure rate shall be estimated graphically on semi-logarithmic paper using the general equation:

$$\lambda_T = C e^{\frac{a}{T}} \quad (3)$$

where:  $\lambda_T$  = failure rate at temperature T  
 $T$  = temperature in degree Kelvin  
 $C$  = a constant, depending on initial conditions  
 $e$  = base of the natural logarithm, = 2.72...  
 $a$  = slope

Using equation (3) for a reference temperature R, we find:

$$\lambda_R = C e^{\frac{a}{R}}$$

from which we can obtain:

$$C = \frac{\lambda_R}{e^{\frac{a}{R}}} = \lambda_R \cdot e^{-\frac{a}{R}} \quad (4)$$

Replacing this value C in equation (3) we arrive at the general equation:

$$\lambda_T = \lambda_R e^{-\frac{a}{R}} \cdot e^{\frac{a}{T}} = \lambda_R e^{+a \left[ \frac{1}{T} - \frac{1}{R} \right]} \quad (5)$$

#### IV - APPENDIX II

To obtain the slope, the following manipulation shall be effected:

$$\lambda = \frac{\ln \lambda_{T_2} - \ln \lambda_{T_1}}{\frac{1}{T_2} - \frac{1}{T_1}} \quad (6)$$

where:  $\ln x$  = natural logarithm of  $x$

The intercept is obtained by:

$$C = \lambda_{T_1} \cdot e^{-\frac{a}{T_1}}$$

where  $\lambda$  was obtained in equation (6)

#### 6.0 Determination of Sample Sizes and Number of Failures Necessary to Demonstrate a Failure Rate:

A. Temperature: In order to estimate the sample sizes and the number of units failed necessary to demonstrate a failure rate, we shall use data obtained in a previous accelerated test (See appendix I-C of 3rd Quarterly Report) in which it was determined that  $\alpha = .5050$ . The objective failure rate being 0.05% per thousand hours at 25°C, equation (5) now becomes:

$$\lambda_T = .0005 e^{-5050 \left[ \frac{1}{T} - \frac{1}{298} \right]}$$

$$\lambda_T = 5 \times 10^{-4} e^{-5.05 [N - 3.36]} \quad (7)$$

where:  $N = \frac{10^3}{T}$

Based on equation (7) it becomes possible to determine the accelerated failure rates. This is shown graphically in Figure II-A, and, in the table below, calculations are shown for five specific temperatures.

Table I - Calculation of accelerated failure rates  
based on Equation (7)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
T°C	°K	1/°K x 10 <sup>3</sup>	N-3.36	-5.05 x (4)	(5)	5 x 10 <sup>-4</sup> x (6)	λ <sub>T</sub>
75	348	2.88	-0.48	2.42	11.30	.00565	.565%
99	372	2.69	-0.67	3.38	29.50	.0145	1.45%
127	400	2.50	-0.86	4.32	76.50	.0382	3.82%
160	433	2.31	-1.05	5.28	198.0	.099	9.9%
200	473	2.12	-1.24	6.25	510.0	.253	25.3%

FAILURE RATE, % PER 1000 HRS

FIGURE II-A

TRANSISTOR FAILURE RATE  
VS  
INVERSE ABSOLUTE TEMPERATURE  
BASED ON

$$\lambda_T = 5 \times 10^{-6} e^{-6.05(N-4.24)}$$

WHERE

$\lambda_T$  = FAILURE RATE  
IN DECIMALS

$$N = \frac{10^3}{T}$$

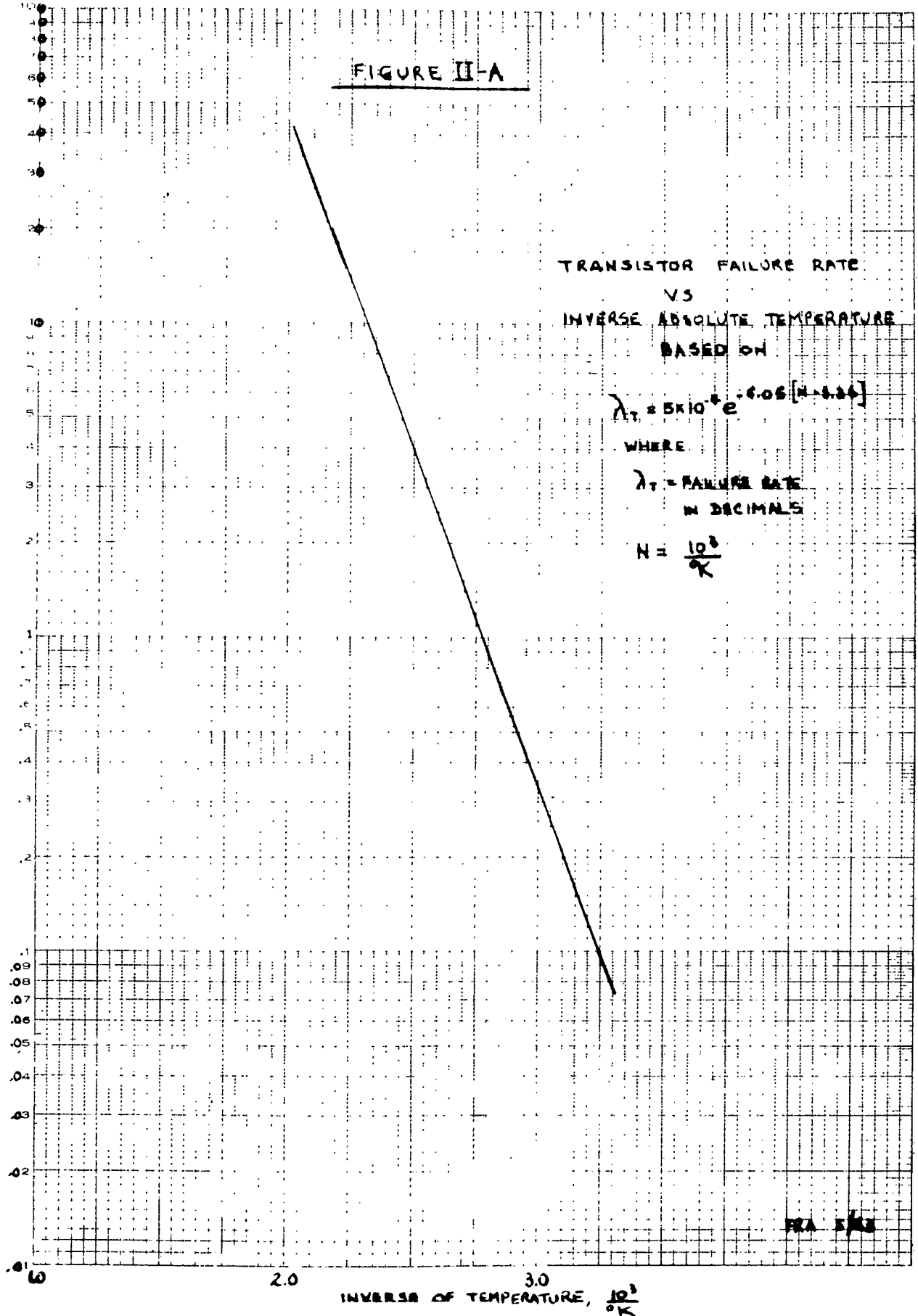


FIG. 5/63



To determine the number of unit-hours necessary to demonstrate a failure rate with 90% confidence we use equation (2). We calculate  $n$  as follows:

$$\lambda \leq \frac{\lambda_m [1 + \frac{\lambda}{n-k} \cdot F]}{F}$$

$$\lambda F \leq \lambda_m [1 + \frac{\lambda}{n-k} \cdot F]$$

$$e^{\lambda F} \leq 1 + \frac{\lambda}{n-k} \cdot F$$

$$e^{\lambda F} - 1 \leq \frac{\lambda}{n-k} \cdot F$$

$$n-k \leq \frac{\lambda F}{e^{\lambda F} - 1} \cdot F$$

$$n \leq \frac{\lambda F}{e^{\lambda F} - 1} \cdot F + k \quad (8)$$

the following table results:

Table 2 - Necessary unit-hours ( $\times 10^3$ ) at selected temperatures to demonstrate  $\lambda > .05\%/1000$  hours for the allowable number of failures. Calculated from equation (8).

Number of failures	Temperature			
	75°C	99°C	127°C	160°C
0	407	160	61	*
1	680	271	104	44
2	944	371	143	61
3	1,183	468	181	77
4	*	*	*	93
5	*	*	*	105
6	*	*	*	*
7	*	*	*	60

\* Not calculated

It is projected to run the tests for 2500 hours. The number of units necessary, then, may be calculated by taking the unit-hours and dividing by the number of hours. This was done, and the following results were obtained:

Table 3 - Number of units put on life test for 2500 hours and number of allowable failures to demonstrate  $\lambda < .05\%/1000$  hours with 90% confidence.

Temperature			
75°C	99°C	127°C	160°C
270	108	57	42
1	1	2	5
$\lambda$			

The total number of units placed on accelerated temperature test will therefore be 501.

B. Power: The accelerated power failure rate is obtained in a manner analogous to that of the temperature. We now need the slope and intercept of the line given by Equation (3).

The following assumptions are made: Given that the case temperature is held at 85°C

1. The failure rate at temperature T when power is on is 1.5 times larger than the failure rate at the same temperature when power is off.
2. The thermal resistance of the transistor is 1.2°C/W.

From these two assumptions and with the help of Figure II-A, we calculate that the failure rate is 100% at a power of 136 watts; (case at 85°C) that the failure rate is 2.1% at a power of 20 watts. (case at 85°C)

$$\lambda_p = C e^{\frac{p}{\theta}}$$

B is calculated from the analogous of Equation (6) as:

$$B = \frac{\ln \lambda_{p2} - \ln \lambda_{p1}}{\frac{1}{p_2} - \frac{1}{p_1}} = \frac{\ln 1.0 - \ln .021}{\frac{1}{20} - \frac{1}{163}} = \frac{-0.04263}{-3.86} = -90.5$$

The intercept is calculated as:

$$C = 1.0 e^{\frac{90.5}{1.2}} = 1.95$$

The accelerated equation for power now becomes:

$$\lambda_p = 1.95 e^{-\frac{p}{90.5}} \quad (9)$$

This is plotted as Figure II-B.

For practical reasons it is attractive to use the same failure rates (and thus the same sample size and number failed) for the power and the temperature tests. We shall therefore calculate from Equation (9) the power requirements to achieve a certain failure rate so that the results shown in Table 3 may be used.

From Equation (9):

$$\lambda_p = e^{-\frac{1.95}{90.5/p}}$$

$$\ln \left( \frac{\lambda_p}{1.95} \right) = -\frac{90.5}{p}$$

$$\frac{\ln \left( \frac{\lambda_p}{1.95} \right)}{90.5} = -\frac{1}{p} \quad (10)$$

#### IV - APPENDIX II

To determine the number of unit-hours necessary to demonstrate a failure rate with 90% confidence we use equation (2). We calculate  $n$  as follows:

$$\lambda \leq \frac{\ln \left[ 1 + \frac{k+1}{n-k} \cdot F \right]}{t}$$

$$\lambda t \leq \ln \left[ 1 + \frac{k+1}{n-k} \cdot F \right]$$

$$e^{\lambda t} \leq 1 + \frac{k+1}{n-k} \cdot F$$

$$e^{\lambda t} - 1 \leq \frac{k+1}{n-k} \cdot F$$

$$n-k \leq \frac{k+1}{e^{\lambda t} - 1} \cdot F$$

$$n \leq \frac{k+1}{e^{\lambda t} - 1} \cdot F + k \quad (8)$$

the following table results:

**Table 2 - Necessary unit-hours ( $\times 10^3$ ) at selected temperatures to demonstrate  $\lambda < .05\%/1000$  hours for the allowable number of failures. Calculated from equation (8).**

	Temperature				
	75°C	99°C	127°C	160°C	200°C
Number of failures					
0	407	160	61	*	*
1	680	271	104	44	*
2	944	371	143	61	*
3	1,183	468	181	77	*
4	*	*	*	93	*
5	*	*	*	105	45
6	*	*	*	*	53
7	*	*	*	*	60

\* Not calculated

It is projected to run the tests for 2500 hours. The number of units necessary, then, may be calculated by taking the unit-hours and dividing by the number of hours. This was done, and the following results were obtained:

**Table 3 - Number of units put on life test for 2500 hours and number of allowable failures to demonstrate  $\lambda < .05\%/1000$  hours with 90% confidence.**

	Temperature				
	75°C	99°C	127°C	160°C	200°C
$n$	270	108	57	42	24
$k$	1	1	2	5	7

The total number of units placed on accelerated temperature test will therefore be 501.

#### IV - APPENDIX II

**B. Power:** The accelerated power failure rate is obtained in a manner analogous to that of the temperature. We now need the slope and intercept of the line given by Equation (3).

The following assumptions are made: given that the case temperature is held at 85°C

1. The failure rate at temperature T when power is on is 1.5 times larger than the failure rate at the same temperature when power is off.
2. The thermal resistance of the transistor is 1.2°C/W.

From these two assumptions and with the help of Figure II-A, we calculate that the failure rate is 100% at a power of 136 watts; (case at 85°C) that the failure rate is 2.1% at a power of 20 watts. (case at 85°C)

$$\text{then: } \lambda_p = c e^{\frac{B}{P}}$$

B is Calculated from the analogous of Equation (6) as:

$$B = \frac{\ln \lambda_{p2} - \ln \lambda_{p1}}{\frac{1}{P_2} - \frac{1}{P_1}} = \frac{\ln 1.0 - \ln .021}{\frac{1}{20} - \frac{1}{136}} = \frac{3.86}{-0.04263} = -90.5$$

The intercept is calculated as:

$$C = 1.0 e^{\frac{90.5}{136}} = 1.95$$

The accelerated equation for power now becomes:

$$\lambda_p = 1.95 e^{-\frac{90.5}{P}} \quad (9)$$

This is plotted as Figure II-B.

For practical reasons it is attractive to use the same failure rates (and thus the same sample size and number failed) for the power and the temperature tests. We shall therefore calculate from Equation (9) the power requirements to achieve a certain failure rate so that the results shown in Table 3 may be used.

From Equation (9):

$$\frac{\lambda_p}{1.95} = e^{-90.5/P}$$

$$\ln \left( \frac{\lambda_p}{1.95} \right) = -90.5/P$$

$$P = -\frac{90.5}{\ln \left( \frac{\lambda_p}{1.95} \right)} \quad (10)$$

FAILURE RATE, % PER 1000 HOURS

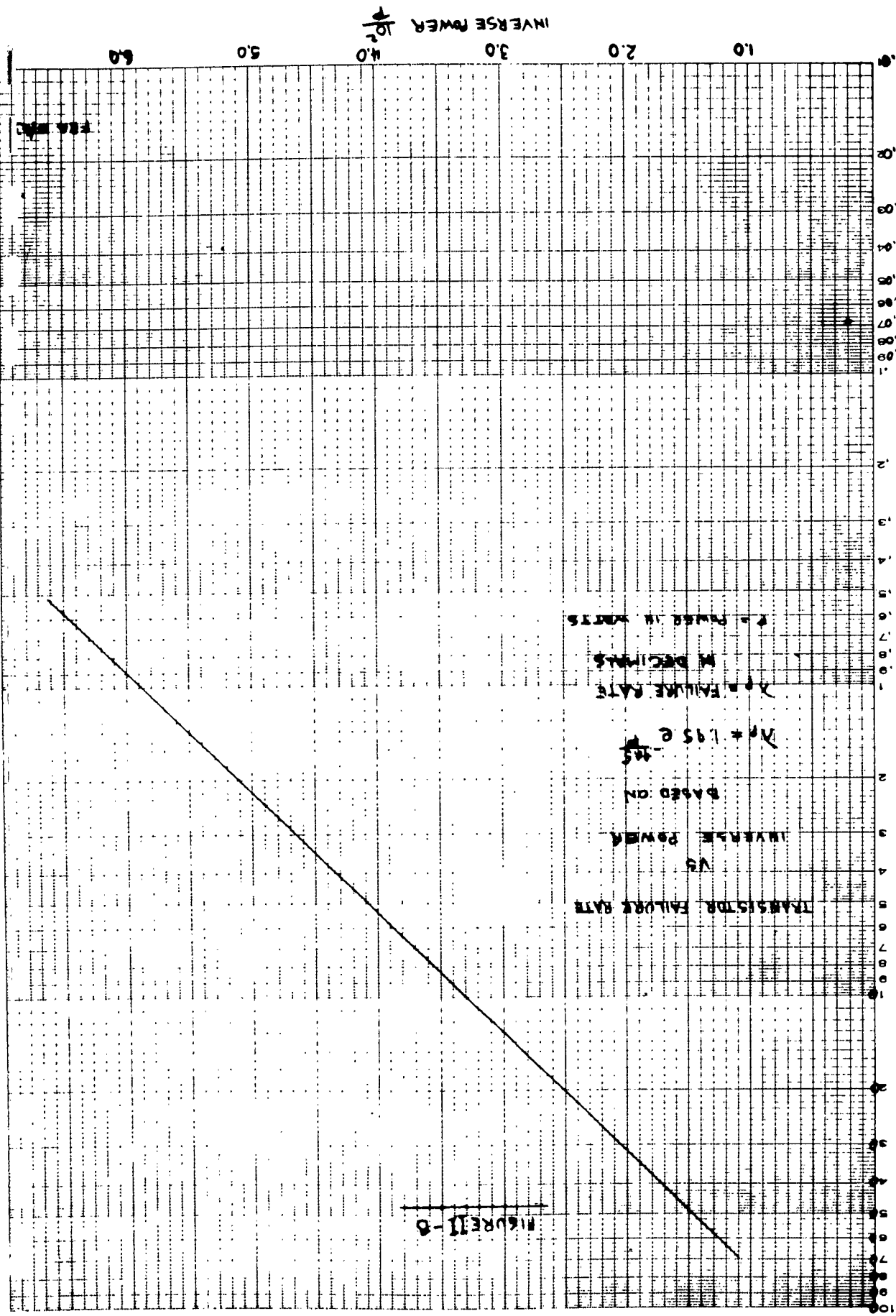


FIGURE II-8

#### IV - APPENDIX II

With the failure rates obtained in column ⑦ of Table 1 and the help of Equation (10) we present Table 4:

**Table 4 - Power requirements to meet a given accelerated rate**

(1)	(2)	(3)	(4)
$\lambda_p$	$\lambda/1.95$	$\ln \textcircled{2}$	$-90.5/\textcircled{3}$
.00565	.00290	-5.85	15.4
.0145	.00745	-4.90	18.4
.0382	.0196	-3.93	23.0
.099	.0507	-2.98	30.4
.253	.130	-2.04	44.4

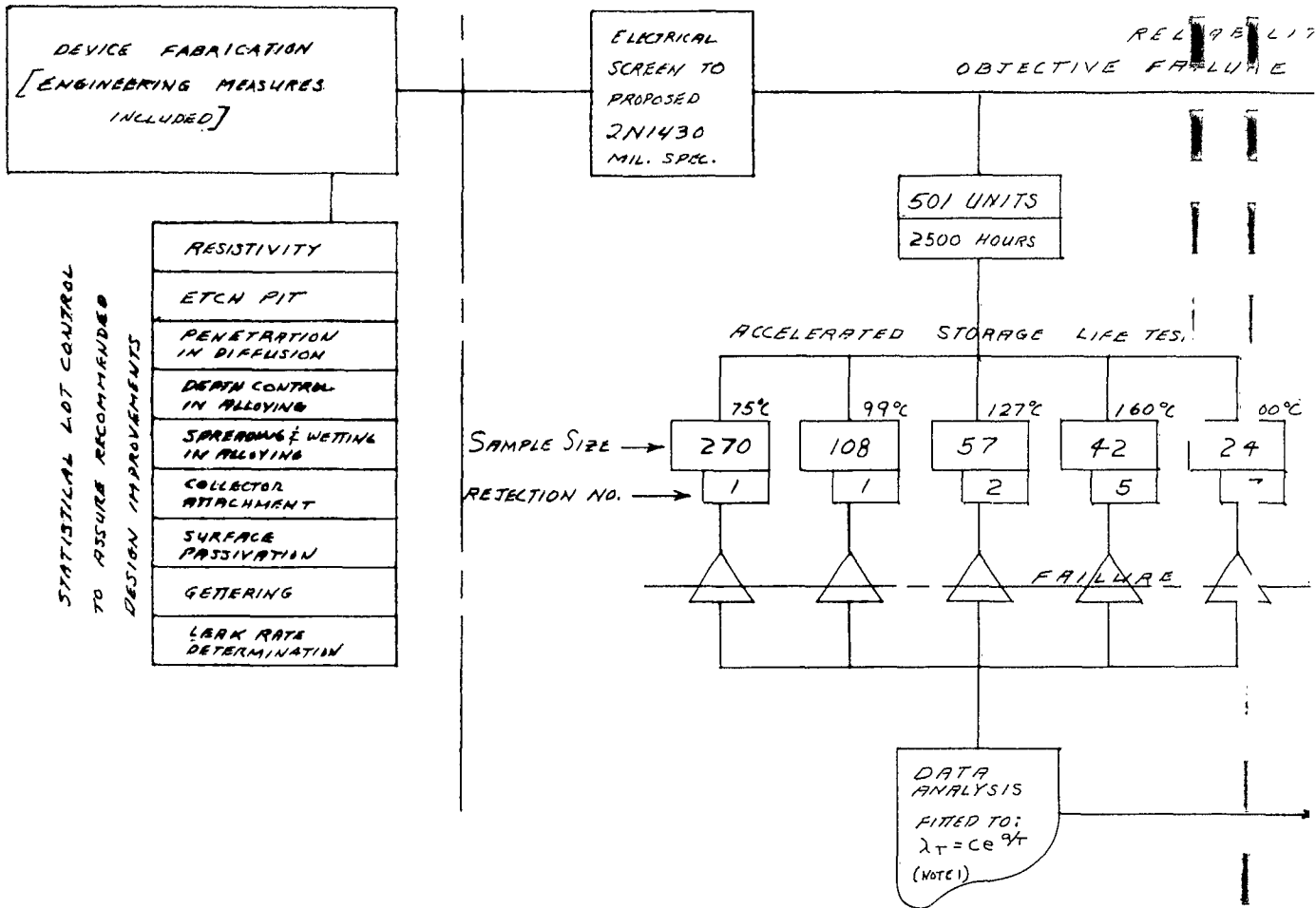
Table 3 is now reproduced for the sake of completeness as Table 5.

**Table 5 - Number of units put on life test for 2500 hours and number of allowable failures to demonstrate  $\lambda < .05\%/1000$  hours with 90% confidence.**

	15.4 watts	18.4 watts	23.0 watts	30.4 watts	44.4 watts
$n$	270	108	57	42	24
$r$	1	1	2	5	7

The number of units placed on accelerated test will, therefore, be: 501 on temperature and 501 on power for a total of 1002 units.

# BENDIX TYPE 2N1430 PRODUCTION



NOTE 1. GENERAL EQUATION FOR ACCELERATION CURVE OF  $\lambda_x \leq 0.05\%$  PER 1000 HRS AT 25°C. THIS EXPRESSION IS FURTHER DESCRIBED IN PARA. 5.0 OF APPENDIX I

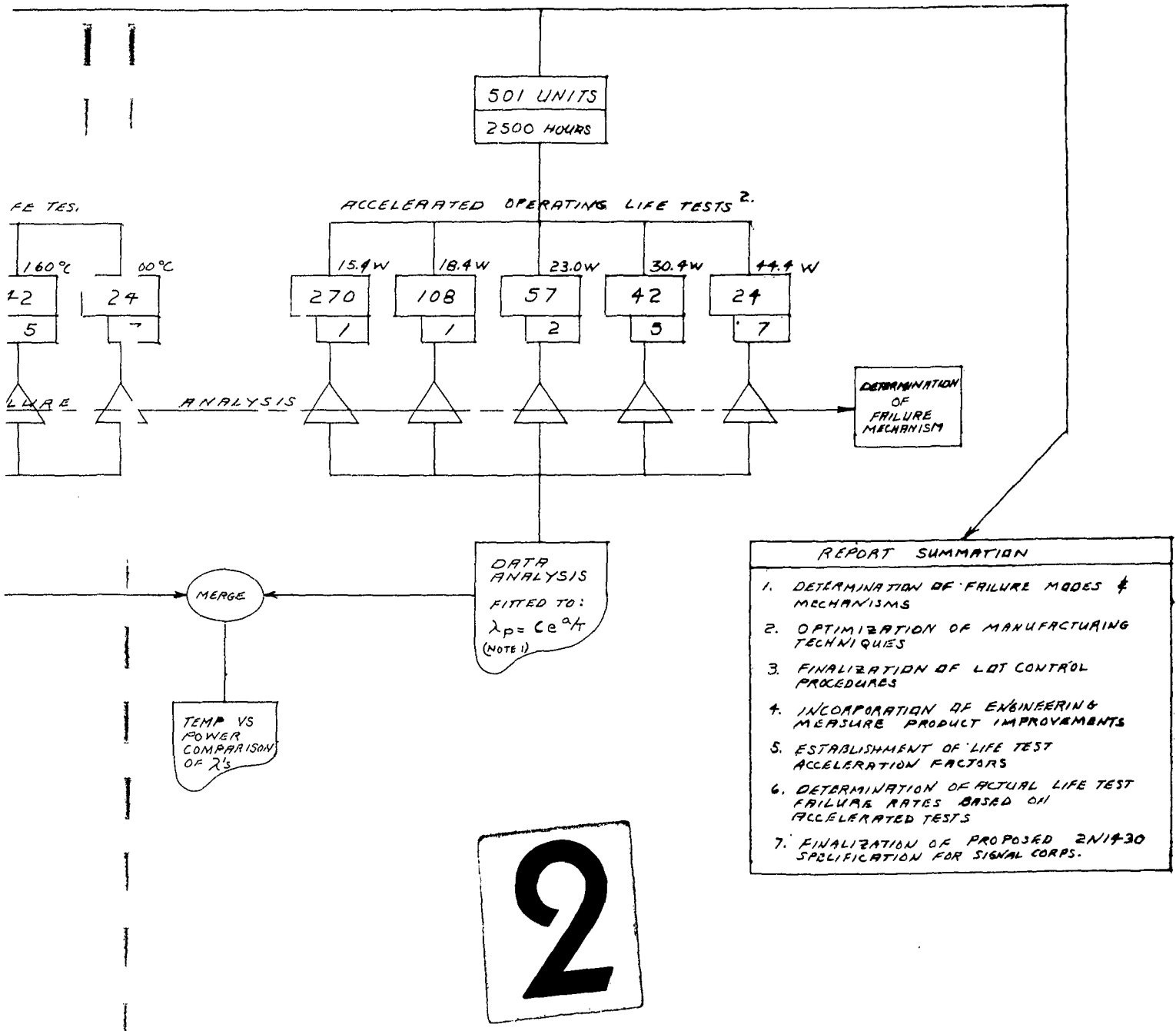
NOTE 2. TEMPERATURE FIXED AT 85°C FOR ALL TESTS

1

# REDUCTION ENGINEERING MEASURE

## APPENDIX III

RELIABILITY DETERMINATION  
FAILURE RATE  $\leq 0.05\%$  PER 1000 HRS AT  $25^{\circ}\text{C}$





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